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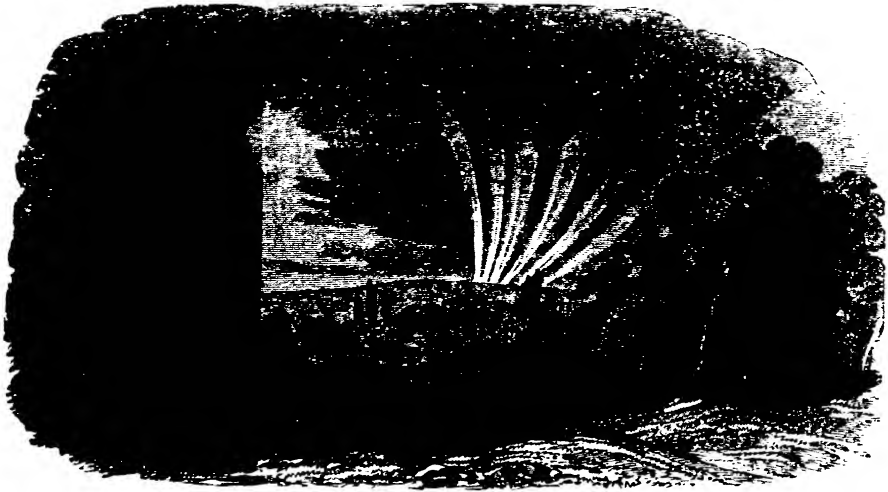

THE COMET OF 1744.

THE

HEAVENS AND THE EARTH;

FAMILIAR ILLUSTRATIONS OF ASTRONOMY.

BY THE

REV. THOMAS MILNER,

M.A., F.R.G.S.

, " OUR HOME ISLANDS;" "THE OTTOMAN EMPIRE," ETC.

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THE HEAVENS AND THE EARTH.

CHAPTER I.

CHARACTERISTICS AND USES OF ASTRONOMICAL SCIENCE.

Astronomy—Its Objects and Antiquity—Its Peculiarity—The Telescope—Celestial Time-Keepers—Constellation of the Cross—Divisions of Time—Determination of Ancient Dates—Celestial Guide-Posts—Determination of Geographical Positions—Mode of finding the Latitude—Longitude at Sea—The Chronometer—Lunar Method—Nautical Stars—Voyage of Captain Basil Hall—Religious Aspects of Astronomy.

The term Astronomy is derived from the two Greek words, ἀστήρ (*aster*) "a star," and νόμος (*nomos*) "a law." It denotes that branch of natural knowledge which treats of the number, distance, magnitude, motions, and physical constitution of the great bodies that compose the universe, the laws that regulate their movements, with the means and processes by which accurate conclusions are attained respecting their phenomena. This science is one of the most fascinating, ancient, and peculiar, of the secular pursuits of the human mind. It is also of the highest importance in the arts of life, while equally adapted to expand the intellect, improve the character, elevate and strengthen devotional feeling, when prosecuted "as seeing Him who is invisible," the Creator, Upholder, and Gover-

nor of all things. Objects are dealt with which gratify the senses by displays of the sublime and beautiful, appreciable by rustic ignorance as well as cultivated taste; and highly favourable to inspire the heart, already under the power of religion, with humility and grateful adoration.

> "My heart is awed within me, when I think
> Of the great miracle which still goes on
> In silence round me—the perpetual work
> Of Thy creation, finished, yet renewed
> For ever."

There is the Sun "going forth in his might," an orb of unrivalled lustre and majesty, diffusing the genial blessings of light, warmth, and fruitfulness, not only to our own world, but, if we may judge from effects evident to ourselves, through the wide range of a stupendous empire: the Moon "walking in brightness," exhibiting successive phases, from a thin crescent to a perfect circle, and shining in each with that softened radiance which the eye can steadily contemplate, though sufficient to enable us to dispense largely with artificial illumination: the Planetary and Stellar worlds, diamond-like points, glittering with varied brilliance in the firmament, solemn and stedfast in their silence, calm and regular in their progression, as if in those mysterious abodes there was nothing akin to the strife of human passion.

These imposing bodies arrested the attention and drew forth the admiration of mankind in the very earliest ages, whether shepherds in the fields, hunters on the plains, mariners at sea, or citizens in walled towns. Careful watching soon followed upon wonder and delight, and was strongly stimulated by the obvious utility of sun, moon, and stars, to human subsistence

and comfort. In fact, celestial observation is necessarily coeval with the date of man's existence upon the earth; and having been endowed with capabilities to appreciate the glory and adaptations of the sensible objects around him, he accomplishes one design of his being, and fulfils a sacred obligation, in applying himself with a reverent and religious spirit to apprehend creation's wondrous scheme. "Lift up your eyes on high, and behold who hath created these things, that bringeth out their host by number." Is. xl. 26. "Stand still, and consider the wondrous works of God." Job xxxvii. 14.

We have spoken of astronomy as a peculiar as well as ancient and fascinating study. Its character is unique in the circle of the sciences, being distinguished from all other branches of knowledge by the fact, that the objects of which it treats are perfectly inaccessible, removed from us by mighty spaces. The meteorologist is bathed and penetrated by the atmosphere he examines; the botanist can closely inspect the entire organization of the plant he describes; the zoologist can do the same with the animal; and the chemist has the elements upon his table on which he operates. It is otherwise with the great components of the universe. They are eminently remote bodies. The moon, the nearest of them, is nearly a quarter of a million of miles apart from us; the sun is many millions; the exterior planets are hundreds of millions; and the nearest of the fixed stars are at an almost incalculable distance. Even our own globe—a celestial body to the astronomer—is no exception to this remark, for it is with the earth as *a whole* that he is concerned, and only a very small portion of its surface can be surveyed at once.

Most peculiar likewise is the instrument by which the grand discoveries of the science have been made, for the telescope is distinguished by its origin, character, and field of operation, from all other mechanical contrivances. It cannot be considered as the offspring of man's wisdom and device, for it was not, properly speaking, an invention. A maker of spectacles at Middleburg stumbled upon the discovery owing to his children directing his attention to the enlarged appearance of the weathercock of a church, as accidentally seen through two spectacle glasses, held between the fingers some distance apart. This was one of childhood's inadvertent acts; and seldom has there been a parallel example of mighty results springing out of such a trivial circumstance. It is strange to reflect upon the playful pranks of boyhood being connected in their issue, and at no distant date, with enlarging the known bounds of the planetary system, resolving the nebula of Orion, and revealing the richness of the firmament. The instrument is further perfectly novel in its origin and purpose. The noblest monuments of human mechanics have either been elaborated from designs supplied by nature, or been extensions of ideas already familiar. Thus the stately merchant vessel or man-of-war is but a huge copy of the tiny shell of the nautilus afloat upon the deep, and the sere and yellow leaf drifting at random on the waters, as to the principle of their buoyancy. Schoolboys playing at bubbles indicated the achievements of the aëronaut, long before balloons rose in the atmosphere and ascended above the clouds. The complex steam-engine had its germ in the kettle of the domestic hearth. But the "optic glass," which brings objects into view, that without it would for ever remain invisible,

involved a principle altogether new. Experience knew no prototype, and nature offered no analogy. Unlike all other things of human construction, its special province is remote and celestial, though applicable to terrestrial purposes. Considerations of this kind establish for the telescope a high claim to admiration and regard, as a singular gift of Providence to the human race, intended to illustrate to them the extent, variety, and magnificence of the Divine dominions.

In arranging and conducting the affairs of life, astronomical determinations are of the highest utility, increasingly so as civilization advances, and nations separated by great breadths of ocean are united by the bonds of commerce and friendship. From the earliest ages, the stars have been useful time-keepers and guide-posts to the dwellers upon the earth. It was soon known, as the result of ordinary observation, that certain stars or groups assume a particular aspect at regularly recurring intervals; and hence in rude states of society, when there were no time-pieces, such aspects marked out the progress of the night. Charles' Wain, the popular name with our ancestors for the constellation of the Great Bear, was a serviceable dial to them, ever wheeling round the pole, and altering its relative position to return to it again. Hence the remark of the carrier in Shakespeare, "An't be four by the day; Charles' Wain is over the new chimney, and yet our horse not packed." At present, in the southern hemisphere, the constellation of the Cross answers the same purpose, for the two great stars which mark the summit and the foot, are perpendicular to each other on passing the meridian. At certain seasons of the year, the Cross is thus erect at mid-

night, and more or less inclined to the horizon in opposite directions at preceding and subsequent intervals. "No other group of stars," says Humboldt, "exhibits to the naked eye an observation of time so easily made. How often have we heard our guides exclaim in the savannahs of Venezuela, or in the deserts extending from Lima to Truxillo, 'Midnight is past; the Cross begins to bend!' How often these words reminded us of that affecting scene, where Paul and Virginia, seated near the source of the river of Lotaniers, conversed together for the last time; and when the old man, at the sight of the Southern Cross, warns them that it is time to separate!"

To be able to divide time into proportionate parts which are certain and invariable, is an arrangement of the utmost importance to the affairs of society; and this is fully attained by scientific observation of the heavenly bodies, whose revolutions in obedience to unalterable laws are not liable to the changes to which artificial movements are subject. The sun's apparent path through the circuit of the heavens gives us the year; the moon's revolution round the globe discriminates the months; and the earth's rotation upon its axis defines the day. To this office of dividing time into definite portions, and furnishing the means of easily computing its progress, the sacred record refers: "Let there be lights in the firmament of the heaven to divide the day from the night; and let them be *for signs, and for seasons, and for days, and for years.*" It deserves remark, that as celestial phenomena supply accurate standards for the measure of time, we can sometimes fix the era of events in history, which are simply chronicled on its page in connexion with coincident solar or lunar positions. Thus Herodotus, and several

ancient writers after him, mention a total eclipse of the sun, which happened while the Medes and Lydians under Cyaxares and Alyattes were engaged in battle, without assigning any date. In order to determine this, we have to look for an eclipse which would be total in Asia Minor, the scene of the engagement, and which will agree with the historical indications. These points have been decided by Mr. Hind in favour of the great eclipse of May 28, B.C. 585, which, according to his computations, was total in Ionia, Lydia, Lycia, Pamphylia, and the southern part of Cilicia. In a similar manner, Halley ascertained the precise day of the landing of Julius Cæsar in Britain, August 26, B.C. 55, guided by the notices in the Commentaries of the commander respecting the full moon and the high tide.

But it is specially in the art of navigation that the labours of the astronomer are of priceless value, for without them it could not be conducted with safety or with speed. In very primitive times, mankind seem to have had recourse to the stars as celestial guide-posts, both in their journeys by land, and voyages on the deep. It is probable, that in the great deserts of the East, where there are few natural landmarks, the discovery was made, that the bright points in the firmament might be serviceable to direct the footsteps of the traveller across them. Diodorus Siculus states, that in the sandy deserts of Arabia, travellers were accustomed to direct their course by the Bears, the two constellations of that name; and the Korán recognises the same fact in the passage — "God has given you the stars to be guides in the dark both by land and sea." In their voyages also, the ancients chiefly referred to the two groups, Ursa Major and

Minor, as indicating the north. Yet while adverse gales must frequently have driven them out to sea, and compelled them to sail at night, they generally crept with caution along the shores, and moored their vessel in the darkness. To venture out of sight of land was deemed an act of extreme audacity, for which, in the words of Horace, the mariner must be endued with a heart of oak, and be girt with triple folds of brass. But now, aided by the resources which science has accumulated, the navigator traverses the trackless ocean, thousands of miles from land, able to determine his place upon the world of waters with almost absolute precision, and steer to port, however he may have been driven to and fro by the winds, and drifted by the currents. It has only been by long and careful watchings of the outer universe, profound investigation of the laws which govern its movements, and a laborious comparison of numerous observations, that the art of navigation has been thus perfected; and the importance of the services of the astronomer, by which alone such a result has been attained, will be appreciated by a moment's reflection upon the many lives and the vast amount of property constantly embarked upon the deep.

The position of a place on the earth's surface is defined by its latitude and longitude. The former is the distance of the place, north or south, from the equator; the latter is its distance, east or west, from a fixed meridian; and the meridian of the Royal Observatory, Greenwich, is invariably with us the standard from which longitude is reckoned. On land, when once the geographical position of any spot has been accurately fixed, or its latitude and longitude taken, the operation need not be repeated, for the record of it will

serve for all time. But at sea the case is different. The ship passes on, leaving no mark upon the face of the ocean to denote the spot of which the latitude or longitude has been ascertained; and it can never be defined again but by a repetition of the process. Hence the mariner is under the necessity of constantly determining the place of his vessel by new independent investigations; and this is part of the ordinary day's work of a ship.

The easiest, and in general the safest method to determine the latitude at sea is from the meridian altitude of some heavenly body. The object chosen is always the sun, when cloudy or foggy weather does not render it impracticable. With a sextant, as noon approaches, the navigator finds the altitude of the lower limb. By adding the semi-diameter, given him in his tables, he obtains the altitude of the sun's centre. He then subtracts the altitude from 90° which is the distance from the zenith to the horizon; and the remainder is the distance of the sun's centre from the zenith. To this remainder he adds the sun's north, or subtracts its south declination, or distance from the equator, which the Nautical Almanac supplies; and the sum or difference is the latitude of his vessel. There are several other methods of solving the problem, but the one described is usually adopted; and is of course as available to the traveller in the wilderness, as to the mariner at sea. It was owing to the frequent use of the sextant in taking meridian altitudes, that the Africans of the interior spoke of Dr. Livingstone as "the white man who could bring down the sun and moon, and carry them under his arm."

To determine the longitude at sea is a task of greater difficulty, and one of the greatest achievements of

nautical astronomy. It may be obtained, as on land, by any method which shall show the difference between the time of day at the station of the mariner and the time of Greenwich at the same moment. As the earth completes a revolution upon its axis in twenty-four hours, while the great circle of the firmament under which the surface is carried is supposed to be divided into 360 equal parts or degrees, it follows, that one hour of time answers to fifteen degrees of space, and four minutes to one degree. Hence a place where the time is later by an hour than at another must be fifteen degrees to the westward, the earth rotating from west to east; and a place where the time is one, two, or three hours faster, must be respectively fifteen, thirty, or forty-five degrees to the eastward. The problem of the longitude is solved, if the difference of time can be accurately ascertained. In order to facilitate this object, and obtain the Parliamentary reward of 20,000*l.* offered in the year 1714, Mr. John Harrison constructed the chronometer, a watch adapted to register Greenwich time with the greatest possible accuracy; for to find the time at the ship is comparatively easy. He won the prize; and chronometers have now been brought to such a high degree of perfection by the skill of modern artisans, that if they were only required to note the time for a few weeks, they might be depended upon with safety. But voyages last for months, sometimes for years; and, at sea, delicate mechanism is peculiarly liable to be deranged by jerks and vibrations, local attractions, and alterations of temperature. Valuable, therefore, as is the instrument, other means of solving the problem are indispensable to the safety of navigation; and in the heavens the astronomer has found a chronometer of Divine workmanship,

which keeps time with unfailing precision, needs no winding up, never requires re-adjustment, is unaffected by heat and cold, storm and tempest, and will run on for the benefit of mankind till there shall be "time no longer."

The common method of determining the longitude at sea is by observation of the moon, and is therefore called the lunar method. The angular distance of the moon from the sun, the planets, and certain conspicuous stars lying in or near her path, is computed and predicted for every three hours, and for two or three years in advance; and these distances, with their corresponding Greenwich time, are given in the Nautical Almanac. The "nautical stars," or those selected for this service, are the following:—

a Arietis, the principal star in Aries, but of the second magnitude.

Aldebaran, of the first magnitude, in Taurus, easily distinguished by its red colour.

Pollux, of the second magnitude, in Gemini, readily known by its companionship with the brighter Castor.

Regulus, a first-class star, in the breast of Leo, hence often called Cor Leonis, the Lion's heart.

Spica Virginis, a first-class star in Virgo, remarkably conspicuous from being insulated in a dark surrounding field, only a single minute neighbour being visible.

a Aquilæ, generally known as Atair, of the first magnitude.

a Pegasi, a second-class star, generally termed Markab.

Antares, of the first magnitude, in Scorpio, distinguished by its fiery red colour.

Fomalhaut, a first-class star, in Piscis Australis.

An observer at sea, wishing to know his longitude, measures with the sextant the distance of the moon from some of these stars, a planet, or the sun; he learns from the Nautical Almanac the hour for the same distance at Greenwich; and knowing the hour where he is, the difference of time gives him his longitude. There are several circumstances to be attended to in the process which need not be detailed. Simple as it appears, and has become in reality, it has exercised the ingenuity and taxed the exertions of the greatest minds, for obviously it could never have been practicable unless the whole theory of the lunar motions had been completely mastered. Thus, to borrow from the fine representation of Sir John Herschel, the visible surface of the celestial vault may be compared to a vast dial-plate; the stars are as fixed marks distributed upon it; the moon is a hand in motion among them, leaving one and approaching another, on her monthly circuit; the whole, with the almanac, answering the purpose of a clock in the heavens, marking Greenwich time to our sailors in every part of the globe, and enabling the skilful seaman to estimate the position of his vessel, though no landmark may have been seen for weeks, and no object have been visible but the billowy deep, the stormy petrel, and the changeful sky.

The late Captain Basil Hall, one of the most scientific officers in the navy, relates the following interesting incident, illustrating the dependence which may be placed on the lunar method of determining a ship's course, when the distances are taken with accuracy, and the computations are made with care. He once sailed from San Blas, on the west coast of Mexico; and after a voyage of eight thousand miles, occupying

eighty-nine days, he arrived off Rio de Janeiro, having in this interval passed through the Pacific Ocean, rounded Cape Horn, and crossed the South Atlantic, without making land, or seeing a single sail except an American whaler. When within a week's sail of Rio, he set seriously about determining by lunar observations the position of his ship, and then steered his course by those common principles of navigation which may be safely employed for short distances between one known station and another. Having arrived within what he considered from his computations fifteen or twenty miles of the coast, he hove to, at four o'clock in the morning, to await the break of day, and then bore up, proceeding cautiously, on account of a thick fog. As this cleared away, the crew had the satisfaction of seeing the great Sugar-Loaf Rock which stands on one side of the harbour's mouth, so nearly right a-head, that they had not to alter their course above a point, in order to hit the entrance of the port. This was the first land they had seen for nearly three months, after crossing so many seas, and being set backwards and forwards by innumerable currents and foul winds. The effect upon all on board was electric, and giving way to their admiration, the sailors greeted the commander with a hearty cheer.

While thousands of lives are annually conveyed in safety across the ocean, with property amounting to the value of many millions, owing to the determinations of astronomy, together with the ability of commanders to turn their instruments of observation upon the sky, these starry heavens should fulfil a still higher purpose, of suggesting religious thought and stirring religious feeling. No science indeed can, by its own power, cleanse the conscience, purify the heart, and raise it to

its Maker. But all science may become a valuable auxiliary to religion in the renewed mind; and specially that which brings before us the mighty distances, magnificent orbs, and harmonious movements which the universe discloses. "The heavens declare the glory of God, and the firmament showeth his handy-work;" "The invisible things of Him from the creation of the world are clearly seen, being understood by the things that are made."

> "Philosophy, baptized
> In the pure fountain of eternal love,
> Has eyes indeed; and, viewing all she sees
> As meant to indicate a God to man,
> Gives Him his praise, and forfeits not her own."

The uniformity of plan observable in the universe greatly sustains faith in the existence and providence of "One God and Father of all, who is above all, and through all." It excludes as decisively as do the Scriptures the idea of "lords many" exercising dominion, and holding the supremacy, in the realm of creation. So far as we can extend investigation into the depths of space, great general laws are found to prevail. The light that gilds the hills, valleys, and oceans of our globe, glows also in the stars, similar in its properties and uniform in its motions, from whatever star or sun it emanates. The law of gravitation, too, which moulds a drop of water, unites the atoms that compose the earth, forms the spherical masses of the planets, and combines them into one system, is plainly in operation in a host of worlds at a distance beyond all human measurement There are, however, endless diversities of detail combined with this grand uniformity of plan in the empire of nature.

While "no man hath seen God at any time," the

surrounding universe presents to the eye of sense a visible demonstration of his perfections; and speaks of him silently but impressively to the hearing ear and understanding heart. It tells us that his counsels are stable, by the unfailing regularity with which seasons return, days and nights alternate, and the lights of the firmament are displayed;—that his wisdom is infinite, for while the planetary bodies, and perhaps entire solar systems, are in perpetual motion, they are maintained undisturbed in mutual relation, from age to age, by the nice adjustment of attractive and projectile forces;—that his power is absolute, unlimited, and irresistible, as of necessity it must be, creating and upholding all things;—that he is good as well as great, for the physical arrangements of our own globe disclose a thousand contrivances for the benefit of its inhabitants;—that he is perfect, unsearchable, and incomrehensible, his works being so, for the remotest orbs within the range of vision are but the advanced sentinels of the army of heaven, whose numbers defy our calculations, while their distance baffles our geometry.

The pages of creation and of Scripture bear testimony of their Author in strict agreement, both as to the nature of their revelations, and the mode in which they are delivered—with simplicity and artlessness, yet with majesty and power. "By the word of the Lord were the heavens made; and all the host of them by the breath of his mouth. For he spake, and it was done; he commanded, and it stood fast." "Ah Lord God! behold, thou hast made the heaven and the earth by thy great power and stretched-out arm, and there is nothing too hard for thee." "Oh the depth of the riches both of the wisdom and knowledge of God!

how unsearchable are his judgments, and his ways past finding out!" "Lo, these are parts of his ways: but how little a portion is heard of him? but the thunder of his power who can understand?" These views are spread through the inspired pages for a great practical purpose. They admonish those who harden themselves against God of the certainty and the terribleness of their punishment, unless there is a timely turning with true repentance from sin and error. They tend to keep alive those habits of reverence and filial fear, so useful and necessary, as a restraint to the Christian, exposed to the temptations of the world; and they are adapted to arm him with that confidence in the Divine care which the followers of Christ are warranted to entertain:—"If God be for us, who can be against us?" "Our help is in the name of the Lord, who made heaven and earth." "What time I am afraid, I will trust in Thee."

CHAPTER II.

ANCIENT AND MODERN VIEWS OF THE UNIVERSE.

Optical Impressions — Ptolemaic System — Copernicus — His Origin and Career — Copernican System — Tycho Brahe — Galileo — His Telescopic Discoveries — Laws of Motion — Persecution of Galileo — Achievements of Kepler — His First Law — Form of the Planetary Orbits — Second Law — Equal Areas described in Equal Times — Third Law — Relation between the Times to the Distances — Results — Great Problem to be solved — Ideas of an Attractive Force — Newton — Reflections on Terrestrial Gravity — Discovers the Law of Universal Gravitation — Laws of Motion — Centripetal and Centrifugal Forces — Publication of the Principia — Its Reception — Death of Newton — Stability of the System.

THE theory of the universe generally embraced by the ancients recognised three fundamental principles— the immobility of the earth — its central position— and the daily revolution of all the heavenly bodies around it in circular orbits. These views being founded upon the evidence of the senses were held with undoubting confidence, and maintained their ground down to a comparatively modern epoch. Age after age, century after century, as mankind occupied their terrestrial habitation, no one ever saw it move, heard it move, or felt it move; and thus supported by the testimony of the eye, the ear, and the touch, the doctrine of its fixed position passed current as an incontrovertible fact. There are times and seasons when natural appearances immediately around us invest this idea with peculiar plausibility. On a summer's eve or winter's night, when away from the thoroughfares of cities, and the winds are hushed, the tranquil aspect of hill and valley, of field, lake, and forest, seems to inti-

mate and typify the eternal repose of the spacious earth to which they belong.

> "How quiet is the night!
> The trees are motionless; the cloudless blue
> Sleeps in the firmament; the thoughtful moon,
> With her attendant train of circling stars,
> Seems to forget her journey through the heavens,
> To gaze upon the beauties of the scene.
> That scene how still! no truant breeze abroad
> To mar its quietness. The very brook,
> So wont to prattle like a merry child,
> Now creeps with caution o'er its pebbled way,
> As if afraid to violate the silence."

Hence, in the infant age of reflection, when observers looked only at the surface of things, the immobility of the earth was accepted as a philosophical truth, which it would have been accounted impious to question.

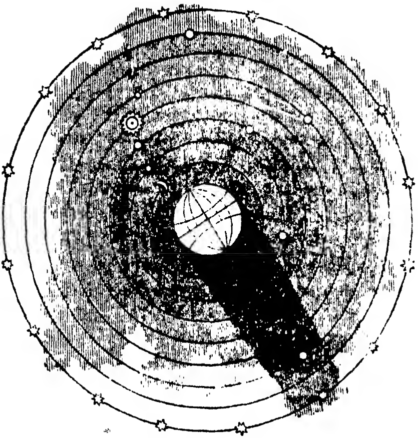
Equally do optical impressions favour the notion of the earth's central position. It is supported by the unvarying configuration of the stars, their unchanging magnitude and brilliancy, with the uniform diameters of the sun and moon, while the scene which on any clear night the heavens present to the eye, is that of a vast hemispherical canopy—a dome bespangled with gems—precisely in the centre of which we seem to stand. The third idea—that of the actual diurnal revolution of the firmament around us—is just as strongly sustained by sensible evidence. In the familiar spectacle of day and night, the sun, moon, and stars are seen to rise in the east, climb the sky, and sink beneath the western horizon, to reappear after a season of invisibility, renewing the same course. Mankind being accustomed to depend implicitly upon the verdict of the senses, the earth was therefore supposed to be constantly at rest, with the great orbs of

day and night, and the vast host of stars, circulating round it every twenty-four hours as the central point. Our word Universe, bequeathed to us by the ancients, implies this conception, being derived from *unus* "one," and *versus* "turning,"—the turning of the firmament with one common motion of rotation. Opinions in harmony with the views upon which astronomical science at present reposes, are indeed attributed to Pythagoras and other Greek philosophers. But they seem to have been held more as fanciful speculations than hypotheses supported by sound arguments drawn from observation.

The name of Ptolemy, who flourished at Alexandria in the second century of our era, is commonly associated with a scheme of astronomy arranged in its leading features according to these first impressions of the senses. It did not originate with him, but was carefully digested by him, and formally proposed in a treatise called in Greek the Syntaxis, but better known under the Arabic name of the Almagest, into which language it was translated. It regarded the earth as the immovable centre, with the sun, moon, planets, and stars, revolving daily round it in the order described by the diagram. Ptolemy was the best scholar of his age; an astronomer, geographer, and mathematician; the first who pointed out the effect of refraction in altering the place of a heavenly body; the author of the important discovery of the evection of the moon; and under the sanction of his name, a system now universally held to be erroneous ruled the mind of Europe for fourteeen centuries.

The scheme has only been delineated in its primitive or simplest form, for very cumbrous machinery was afterwards appended to the outline given. This

became necessary in order to account for movements plainly independent of the supposed daily revolution of the sphere, and in an opposite direction to it, or from west to east, such as the annual apparent motion of the sun, the moon's monthly pilgrimage round the earth, and the courses of the planets in their orbits.



PTOLEMAIC SYSTEM.

☽ The Moon. ☿ Mercury. ♀ Venus. ☉ The Sun. ♂ Mars.
♃ Jupiter. ♄ Saturn. * * * Fixed Stars.

To explain these phenomena, recourse was had to the idea of geometrical centres moving round the earth, not indicated by any bodily existence, while the heavenly bodies described smaller circles, or epicycles, round the imaginary points. Such expedients, besides

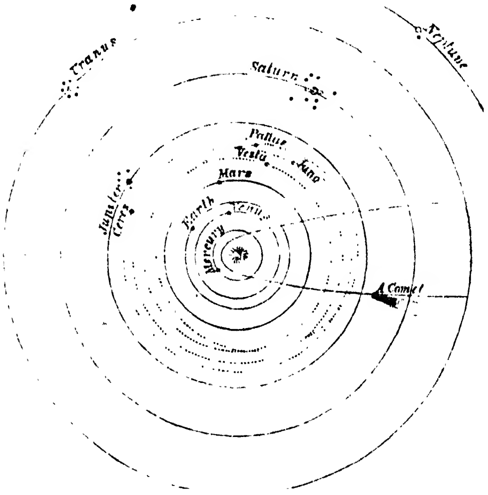
having no evidence in their favour, banished all simplicity from the celestial motions, and introduced the extremest complexity. At last, in the fifteenth century, a philosophic genius was given to the world, to commence the true exposition of nature, by a system which, as subsequently corrected and established, exploded prevailing fallacies, disclosed the simple grandeur of actual arrangements, and now guides the opinions of men in all countries respecting the constitution of the solar universe. "Why do we hesitate," wrote Copernicus, "to give to the earth the mobility suitable to its form, rather than that the universe, whose bounds we do not and cannot know, should revolve? Why should we not confess that the diurnal revolution is apparent only in the heavens, and real in the earth? Since while the ship glides tranquilly along, all external objects appear to the sailors to move in proportion as their vessel moves, and they alone, and what is with them, seem to be at rest."

Nicholas Copernicus was of Sclavonic extraction. He was born on the 12th of February 1473, at Thorn, a town in Polish Prussia, and educated in the University of Cracow. Though intended for the profession of medicine, he was left free to follow the bent of his natural genius, and early displayed great partiality and aptitude for mathematical studies. At the age of twenty-five, he repaired to Italy in order to cultivate astronomy at Bologna; and subsequently became a teacher of mathematics at Rome. Having entered the church, he returned to his native country; and was appointed to a canonry at Frauenberg, a town overlooking the waters of the gulf of Dantzic. Here, in the upper part of a farm-house, situated on the Domberg, or hill of the cathedral, he passed the re-

mainder of his days, living frugally, discharging ecclesiastical duties, practising medicine gratuitously, and meditating upon the phenomena of the heavens. Struck with the simplicity prevalent in all the works and operations of nature, Copernicus was not long in coming to the conclusion that the complicated Ptolemaic scheme could not be a true representation of the celestial movements. On the other hand, he was conscious that apparent motion is not of necessity real. Having travelled by land and water, he had there seen the objects along the roads and the streams appear to be impressed with the motion which was really his own. He had gazed upon the sky by night, and observed how the moon seemed to flit away from the cirrus cloud which obscured her beauty, while the drifting vapour appeared for the moment stationary. He was thus prepared to admit that the firmament might be at rest though apparently in revolution; and that the earth might move notwithstanding its fixity to the senses.

It is uncertain when the views of Copernicus became settled; but in the year 1530, the manuscript of his famous work, "On the Revolution of the Heavenly Bodies," was completed. In this production, the sun is regarded as the immovable centre around which all the planets, including the earth, revolve in circular orbits from west to east, Mercury and Venus being interior to the terrestrial orbit, and Mars, Jupiter, and Saturn, the only planets then known, being exterior;—the earth is supposed to be constantly revolving on a fixed axis from west to east, while traversing her annual orbit, causing the apparent diurnal revolution of the entire firmament;—and the moon is maintained to revolve in a monthly orbit round the earth, while

carried with it around the sun. These views, which had floated as disjointed speculations in the ancient world, were embraced and combined by Copernicus in a



COPERNICAN SYSTEM.

harmonious system, after long and profound reflection upon observed phenomena. They evince great mental independence and grasp of intellect. Having consented to publish his treatise, the first printed copy is said to have been handed to him as he lay upon his death-bed, in the year 1543. His remains were interred in

the cathedral of Frauenberg, where a simple tablet bearing a globe now marks his tomb. Tradition commemorates him as gentle in his manners, and stedfast in his friendships; seldom going abroad, or conversing except upon serious or scientific subjects. It is remarkable that his work was patronised by Gisias a bishop, and Schomberg a cardinal, while it was dedicated to pope Paul III., for its doctrines of the diurnal and orbital motions of the earth were afterwards condemned by the Romish church as heretical, and the volume was placed in the *Index Expurgatorius.* It was not till the year 1821 that the papal excommunication was revoked—a practical confession of pontifical fallibility with reference to a point of science and the interpretation of Scripture.

The Copernican system, now demonstrated, had at first only simplicity and probability in its favour, while mechanical and other objections might be advanced against it, which could not then be refuted. There is no escape from one of two alternatives, either that the earth rotates upon its axis in twenty-four hours, or that the heavens are carried round it in that space of time. Milton thus states the difficulty connected with the latter, the older and the obvious supposition:—

"When I behold this goodly frame, this world,
Of heaven and earth consisting; and compute
Their magnitudes; this Earth, a spot, a grain,
An atom, with the firmament compared
And all her number'd stars, that seem to roll
Spaces incomprehensible (for such
Their distance argues, and their swift return
Diurnal) merely to officiate light
Round this opaceous Earth, this punctual spot,
One day and night; in all their vast survey
Useless besides; reasoning I oft admire,
How nature, wise and frugal, could commit
Such disproportions, with superfluous hand
So many nobler bodies to create,

Greater so manifold, to this one use,
For aught appears, and on their orbs impose
Such restless revolution day by day
Repeated, while the sedentary Earth,
That better might with far less compass move
Served by more noble than herself, attains
Her end without least motion."

More is now known of "spaces incomprehensible" than was apprehended in the age of Milton. It can be demonstrated, that the nearest star to our system is at a distance at least 206,265 times greater than that of the sun from the earth, which, in round numbers, is 95 millions of miles. Therefore we have 206,265 × 95,000,000, or nearly twenty billions of miles, for the minor limit within which no star can lie. This line, light, which travels at the prodigious rate of 192,000 miles per second, would require three years and eighty-five days to traverse, or three years may be assumed to be the time, for the sake of simple calculation. But this immense line, supposing the heavens to revolve round the earth, would form the radius of a circle, the circumference of which, six times larger, the star must describe in the space of twenty-four hours. Its velocity must therefore be $6 \times 3 \times 365 = 6{,}570$ times greater than that of light, or equal to upwards of 1,200 millions of miles per second. This velocity is so enormous as to baffle conception; and the supposition of it becomes perfectly incredible when we consider, that, assuming the diurnal rotation of the earth, a point on the equator, where the velocity of rotation is the greatest, will only be carried round at the rate of about seventeen miles per minute.

The middle of the sixteenth century was rendered memorable by the publication of the true system of the world; but another had commenced before it met with any measure of general favour. In the interval, Tycho

Brahe flourished. He was born in 1546, at Knudsthorp in Sweden, then attached to the Danish monarchy; and became the most diligent and accurate astronomical observer that Europe had yet seen. Being put in possession of the small island of Huene, in the Sound, by the favour of his sovereign, together with an annual stipend, he built the famous Uraniburg, or the City of the Heavens. This was a fantastic observatory, furnished with instruments superior to any that had yet been constructed. In this retreat he passed twenty-five years, actively employed in accumulating a mass of observations on the planets, by means of which Kepler was afterwards enabled to discover the laws of their motions. Tycho did not become a Copernican, but proposed a system which bears his name, the Tychonic. He maintained the earth to be immovable in the centre of the universe; the planets to revolve around the sun; and the sun, with them, to be carried in an annual revolution round the earth. This was an intermediate scheme. It never enjoyed any real estimation; and has somewhat obscured his fame. But he was seated, to use the fine simile of Bailly, on the confines of two ages, partaking of the darkness which preceded, and of the light which came after him. Compelled to leave his island home, he dismantled Uraniburg, and removed his books and instruments to Prague, where he died in 1601, after having been joined by Kepler, who turned to fine account the rich stores of observation placed at his disposal.

Soon after the opening of the seventeenth century, the world received the telescope, and discoveries were made by its help, which silenced many popular objections to the doctrines of Copernicus, and gathered in their favour a large amount of circumstantial proof.

Thus Venus was seen to exhibit successive phases; the solar spots were discerned, and the rotation of the sun upon its axis demonstrated from them—the very motion hypothetically assumed with reference to the earth; and the satellites of Jupiter were detected, forming a miniature exhibition of the solar system itself. These were the achievements of Galileo, the first constructor of a telescope available for scientific purposes. He was a native of Pisa in Italy, born in the year 1564; and became professor of mathematics in the university of that city, and afterwards in that of Padua. His first instrument was completed in the year 1609. But Galileo is more distinguished by his researches respecting the laws of motion, and other branches of mechanical philosophy, than by his telescopic discoveries, though the latter are much better known, and are more popularly appreciable than the former. It was alleged by the opponents of the doctrine of the earth's rotation, that if the hypothesis were true, a stone dropped from the summit of a high tower would not fall at the base, as we see it does; for during the few seconds required for its descent, the tower itself would be carried through an arc of several hundred feet, owing to the earth's velocity, and the stone be left far behind before it reached the ground. In a similar manner, it was argued, that birds upon the wing would find the landscape over which they hovered pass away from under them, which would be equally true of an arrow shot, or a stone thrown into the air. Galileo unanswerably showed that a projected body partakes of the motion of the projector, so that the stone, the birds, and the arrow, with the entire atmosphere around the earth, participate in the common progress of the whole mass. He illustrated the point by the remark, that if, in a

vessel under sail, proceeding as rapidly as possible, a heavy body is suffered to fall from the top of the mast, it will strike the deck at the foot of the mast, and not behind it, because participating originally in the common motion of the vessel. So if we throw a ball into the air on shipboard, it falls back into our hand, or if we drop it, it alights at our feet.

The success which rewarded the telescopic observations and physical inquiries of Galileo exposed him to the malevolence of those whose pride would not allow them to abandon opinions once embraced, however false, or whose ignorance rendered them incapable of appreciating the evidence of their fallacy. Clinging to the prejudices of ages, they appealed from the field of argument to the tribunal of the Romish church; and subjected the philosopher, in the decline of life, to ecclesiastical persecution, by representing the doctrine of the earth's motion as dangerous to religion, being contrary to Holy Scripture. It was in fact opposed to the sense of holy writ, as received in that age, but not to the true interpretation. Being cited to appear before the Inquisition, he was required to promise to refrain from expressing his opinions, or to take the alternative of suffering the censure of the church. He made the promise, but did not keep it; and was once more proceeded against for a lapse into heresy. Yielding to infirmity, he had now the mental and moral weakness to succumb to a tyrannical tribunal, and go through the ceremony of formally and solemnly retracting doctrines which he believed to be true. Yet notwithstanding this recantation, he is said to have whispered to one of his friends, after the humiliating act was over, *E pur si muove*, "It moves for all that." It is to be lamented that conscientiousness

and fortitude were not exemplified in the hour of trial. "Had Galileo," as Sir David Brewster remarks, "but added the courage of the martyr to the wisdom of the sage; had he carried the glance of his indignant eye round the circle of his judges; had he lifted his hands to heaven, and called the living God to witness the truth and immutability of his opinions; the bigotry of his enemies would have been disarmed, and science would have enjoyed a memorable triumph." After being immured in the dungeons of the Inquisition about a year, he was permitted to retire to the village of Arcetri, where he died in 1642, the year in which Newton was born.

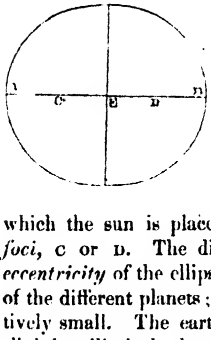
Just as the age of telescopic discovery commenced, Kepler published the first and second of his three great laws, which define the true form of the orbits of the planets, with the principles which regulate their movements and distances. These beautiful and comprehensive theorems, which have won for him the somewhat too ambitious title of the Legislator of the heavens, are the foundations of modern astronomy. They swept at once from the sphere the cycles and epicycles with which the ancients had defaced the fair arrangements of nature; and placed the sublime simplicity of the solar system upon the basis of incontestable evidence. Their discovery was a task of immense labour. It strikingly contrasts in this respect with the telescopic results of his contemporary, Galileo. The latter had little more to do than to use his eyes after the construction of his instrument, while the former had to examine and compare a long series of observations—to calculate, contrive, and think for years—before he reached his demonstrations.

John Kepler, one of the greatest among the great,

was born at Wiel, in the Duchy of Wirtemberg, in the year 1571. Upon Tycho Brahe settling at Prague, he joined him as an assistant in his astronomical labours; and succeeded him on his death in the post of principal mathematician to the imperial court. He held this office under three emperors. But his salary being always in arrear, and often withheld for long intervals, he was harassed with poverty all his days, and had to endure deep domestic misery. To keep his family from starving, he was constrained to publish a kind of prophesying almanac for the vulgar, for which he entertained the utmost contempt. Gifted with a fertile imagination, he revelled in the formation of theories, but abandoned every hypothesis, however long indulged, the moment it was found not to coincide rigidly with fact. In addition to this valuable quality, his industry and perseverance knew no bounds, while truth was sought in the name and under the guidance of its great Author. His discoveries require circumstantial detail.

The first law of Kepler corrected an idea universally held by the ancients, and retained by Copernicus, that the motions of the celestial bodies are necessarily circular. This notion was founded upon the fancy, that the circle is the most perfect of all forms, having neither beginning nor end. Tycho Brahe had long and attentively watched the planet Mars; and, after studying his observations with intense application, Kepler came to the conclusion, that no conceivable circular theory would represent the movements of the planet. He tried in vain no less than nineteen hypotheses to account for the recorded positions. At last he succeeded in determining the form of the orbit to be an ellipse; and discovered it to be the general law of

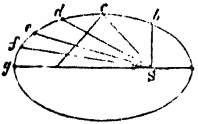
the system, expressed as follows:—*Planets revolve in elliptic orbits about the sun, which occupies the common focus of all these orbits.* The ellipse, an oval figure, is the next simplest curve after the circle; and when but slightly flattened, closely resembles it in form, but has very different properties. In a circle, all the diameters are equal to one another; in an ellipse they are unequal. Thus A.B. in the figure mark the longer diameter, sometimes called the major or transverse axis. The circle has a centre which is equally distant from all parts of the circumference. No such centre belongs to the ellipse. But there are two remarkable points, C. D., from which, if lines be drawn to any part of the circumference, they will be, taken together, equal to the length of the longer diameter. Each of these points is called a *focus*. This beautiful curve represents the form of the planetary orbits, in



which the sun is placed, not at E, but in one of the *foci*, C or D. The distance CE or DE is called the *eccentricity* of the ellipse. It is different in the orbits of the different planets; but is, in most cases, comparatively small. The earth's path round the sun is so slightly elliptical, that a diagram representing it accurately would scarcely be distinguishable from a perfect circle. Yet there is an actual divergence, by virtue of which the distance between the two bodies annually varies by about three millions of miles.

Having ascertained the nature of the path which the planets describe, Kepler determined, in opposition to ancient opinion, retained also by Copernicus, that in

different parts of their orbits they proceed with different velocities, in common obedience to a general principle. This is his *second* law, which is technically expressed by saying that *the radius vector of a planet describes equal areas in equal times.* It will be readily understood. Let S be the sun, and the elliptic curve the path of a planet, represented in different parts of its course. A line drawn from the planet to the sun is called the radius-vector, literally the carrier radius. Let *a*, *b*, *c*, *d*, *e*, *f*, *g*, mark positions successively reached by the planet in the same space of time—a month, for example. The law is, that the space or area within S *a b* is exactly equal to the space within S *b c*, S *c d*, or finally S *f g*, greater length in the latter areas compensating for diminished breadth. Now in consequence of the line drawn from the sun to the planet sweeping over equal areas in equal times, the planet cannot proceed with uniform velocity, but must travel faster or slower, as the case may be, because, while the areas are the same, the arcs at the outer extremity, *ab*, *bc*, *cd*, *de*, *ef*, *fg*, are unequal. Obviously to describe these arcs in equal times, the planet must travel faster from *a* to *b* than from *b* to *c*, and be still further retarded in passing from *c* to *d*. Kepler announced the two laws noticed in a treatise on the "Motions of Mars," published in the year 1609. The book speedily found its way to England, for in a letter from Sir William Lower to his "especial good friend Mr. Thomas Harriot," dated the 6th of February 1610, the knight mentions that he has just been reading Kepler—a meritorious undertaking for a country gentleman in



those days. Most sagaciously also he remarks, that he is in love with the elliptical planetary pathway, "for methinkes it shows a way to the solving of the unknown walkes of comets."

The *third* law of Kepler, announced in the year 1620, disclosed harmonious arrangement in the constitution of the planetary system. It refers to a striking relation subsisting between the mean distances of the planets from the sun, and the times in which they complete their revolution. Its technical form is, that *the squares of the periodic times are to each other in the same proportion as the cubes of the mean distances.* The square of any quantity is found by multiplying it by itself: the cube results from multiplying it by itself twice. As an illustration of the law, let 2 be taken to represent the periodic time of Mercury; 10 the distance of the planet from the sun; 16 the periodic time of Mars; and 40 the planet's distance. Then the squares of the periodic times, or $2 \times 2 = 4$, and $16 \times 16 = 256$, are to each other as the cubes of the distances, or $10 \times 10 \times 10 = 1000$, and $40 \times 40 \times 40 = 64{,}000$. The greater square contains the lesser square just as many times as the greater cube contains the lesser cube. By means of this law, the respective distances of all the planets may be obtained, for we know the earth's period of revolution, with its distance from the sun, and can readily ascertain the period of the other planets by marking their course in the heavens. Hence as the square of the earth's period of 1 year, is to the square of Jupiter's period of 12 years, so will be the cube of the earth's distance of 95,000,000 miles to the cube of Jupiter's distance; and by extracting the cube root of this sum, we obtain the distance itself.

These beautiful generalizations apply not only to the planets but to their satellites; and are necessary consequences of the law of gravitation. They decisively show that the constituents of the system have not been thrown at random into space as unconnected bodies, but are arranged in order by the Almighty wisdom, as related orbs upon which a "true family likeness" has been impressed. Kepler was specially delighted with his last discovery. "What," says he, in his "Harmonics," in which he disclosed it, "I prophesied two-and-twenty years ago; what sixteen years ago I urged as a thing to be sought; that for which I joined Tycho Brahe, for which I settled at Prague, for which I have devoted the best part of my life to astronomical contemplations; at length I have brought to light, and have recognised its truth beyond my most sanguine expectations. It is now eighteen months since I got the first glimpse of light, three months since the dawn, very few days since the unveiled sun, most admirable to gaze on, burst out upon me." His book closes with the fine passage, "I give thee thanks, Lord and Creator, that thou hast given me joy through thy creation; for I have been ravished with the work of thy hands. I have revealed unto mankind the glory of thy works, as far as my limited spirit could conceive their infinitude. Should I have brought forward any thing that is unworthy of thee, or should I have sought my own fame, be graciously pleased to forgive me." He died at Ratisbon, November 15, 1630, whither he had gone to solicit the arrears of his salary from the imperial court. The spot where he was buried in the churchyard of St. Peter's cannot now be identified. But in the public garden which surrounds the city, occupying the site of ancient fortifications, a

small circular temple has been erected to his memory bearing his bust and the ellipse of Mars.

The point to which the mind had now advanced in relation to astronomical science embraced the revolution of the planets round the sun, the form of their orbits, and the law of their velocities and distances. But the solar system was not yet conquered : only the foundation for its conquest had been laid. A mighty problem remained unsolved, and was occupying the thoughts of physical inquirers. Why should the planets describe ellipses, rather than any other course ? How was it that they accomplished a prescribed pilgrimage with undeviating accuracy ? What power poised them in empty space along with the sun himself, and kept them steady in their swift career ? It may seem at first sight presumptuous to grapple with such questions; and that we ought to rest satisfied with the assurance, that God, who built the universe, upholds and governs it by his sovereign will and mighty hand. Yet if the will of the Omnipotent is exerted in the form of law, and if he has been pleased to place the law within the reach of man, it is the right, privilege, and duty of man, according to his ability, to seek to apprehend it. Obviously, in doing this, he may consciously "feel" after God, "find" him in the discovery, and glorify him for it. "Him," says Kepler, "who is too dull to receive this science, I advise, that, leaving the school of astronomy, he follow his own path, and desist from this wandering through the universe; and, lifting up his natural eyes, with which he alone can see, pour himself out in his own heart, in praise of God the Creator; being certain that he gives no less worship to God than the astronomer, to whom God has given to see more clearly with his inward eye, and

who, for what he has himself discovered, both can and will glorify God."

The idea of a general attractive force between the different bodies in the solar system, maintaining them in harmonious movement, dawned upon many minds during the first half of the seventeenth century. Gilbert, an English philosopher, and Kepler, at nearly the same time, but independently, expressed their convictions of its reality. The latter observed the wave of the ocean tide rising and following the course of the moon; and boldly announced the existence of some inscrutable bond between the one and the other. He supposed this mysterious force, by which the waters are heaved in their beds, to reside in the moon: believed that the solid earth itself must experience the same influence, though the immobility of its particles rendered it insensible; and that the moon was similarly acted upon by the earth. He extended the principle of attraction to the sun and the planets; and seems to have imagined that the force varied inversely as the distance. But to Bouillard the honour belongs of having first conjectured what has subsequently been proved to be the real law of nature, that the attractive force varies inversely as the square of the distance. Thus, if the intensity of the solar attraction be represented by a certain value, in the case of a planet at the distance of 600 millions of miles from the sun, it would be reduced to one-fourth of the value, by removing the planet to double the distance. But this wonderful conjecture, with the whole doctrine of a mutual attractive force between the celestial bodies and all particles of matter, remained a conjecture, till Sir Isaac Newton applied the energies of his great mind to the subject. He did not originate the idea of such

a principle existing, but proved its existence, power, and prevalence. He did not divine the nature of the force, but clothed it with the certainty of mathematical demonstration, and showed its explanatory power in accounting for the visible occurrences in the universe.

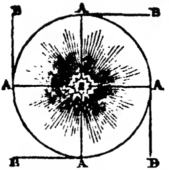
The prince of philosophers, as Newton has been justly styled, was born in the year 1642, at Woolsthorpe in Lincolnshire. The scene of his birth, a farm-house of homely appearance, situated in a small retired valley, has been carefully preserved in honour of his memory. In early life he attended to the business of the farm; but owing to his fondness for books, mechanical contrivances, and mathematics, his friends wisely determined upon preparing him for another vocation; and in his eighteenth year he was sent to Trinity College, Cambridge. His rapid progress in various branches of science soon indicated his future eminence; and at the age of twenty-seven he was appointed to the professorship of mathematics at the University. But before this period he was in possession of many beautiful discoveries, and had made great advances towards solving the problem of the celestial motions. Biographers relate, that having quitted Cambridge in 1666 to avoid the plague, Newton was sitting one day in the garden at Woolsthorpe, when he was led to reflect upon that mysterious power which causes all bodies near the earth to tend towards its centre. This power being apparently unimpaired at the greatest altitudes of the earth's surface, the tops of the highest buildings and the summits of the loftiest mountains, the question proposed itself—"May not the same force extend its influence to a great distance from the earth, even to the moon? May it not be the very reason why the moon is continually drawn away

from the straight line in which projected bodies tend to move; and is thus made to circulate around the earth? And may not a similar principle determine the paths of the planets round the sun?"

After seventeen years of intellectual toil, Newton rigidly demonstrated the attraction of gravitation, of which terrestrial gravity is only an individual example, to be a universal law; and from the sublime height to which the discovery raised him, he looked out upon the grand phenomena of the universe clearly explained because certainly referable to its agency—the stone rolling down the mountain side, the tide swelling in the ocean, the moon wheeling round the earth, the planets revolving round the sun, the satellites circulating round their primaries, and the far-roving comets returning to pay their homage to the monarch of the system. The law may be expressed as follows:—*All bodies in the universe, whether great or small, attract each other, with forces proportioned to their respective quantities of matter, and inversely as the squares of their distances from each other.* This pervading law is remarkable for its simplicity and grandeur. It asserts, first, that every particle of matter attracts, and is attracted by, every other particle. We see no proof of this between small bodies at the terrestrial surface, because it is rendered insensible by the enormously greater mass of the earth which attracts them to its own centre. But falling bodies, whether a pebble from the hand, an apple from the tree, an avalanche from the Alps, or an aerolite from the sky, manifest *the earth's attractive power. Secondly, the mutually attractive force of bodies varies according to their masses*; and thirdly, its intensity depends upon their distance. It diminishes as the square of the distance

increases. If the earth were removed to two, three, or four times its present distance from the sun, the solar attraction would be diminished as the square of these numbers, or be respectively four, nine, and sixteen times less, while its own attraction on the sun would be proportionately decreased. Or if the two bodies were brought in similar degrees nearer, this mutual attraction would be increased in the same ratio. It is said that Newton, towards the close of the investigation, foreseeing the result, became too excited to proceed with his computations, and was compelled to resign the task of completing them to a friend.

The principle of universal gravitation may now be viewed in connexion with the simple laws of motion, derived from a rigorous examination of those moving bodies which are subject to man's closer scrutiny, for the Divine wisdom has impressed them upon bodies celestial as well as terrestrial, as is evident from the certainty with which astronomical predictions are fulfilled. If a body, situated in space and free to move, receives an impulse capable of giving it a certain velocity, it will go forward in a straight line for ever in the direction of the impulse, and with uniform velocity, if no resisting or diverting force is encountered; and it will resume its straight-forward motion, whenever the force that turns it aside is withdrawn. But if a body is acted upon at the same time by two impulses in different directions, the resulting motion will be in a direction determined by their joint action. This condition applies to the case of a body revolving in an orbit, like the moon round the earth, and the planets *round the sun; and is the determining cause of their orbital route. Thus the tangents to the circle, or* the straight lines A. B. in the diagram may repre-



sent the rectilinear path in which the earth or any planet would travel under the influence of the projectile force which launched it into universal space; while the straight lines A S define the different direction it has a tendency to pursue owing to the attraction of the sun at S. *If the solar attraction, or centripetal force, were suspended, the earth would immediately desert the circular route, and fly off at a tangent to it, in the same manner as the stone which the school boy whirls round his head in a sling flies off in a straight line the moment one of the strings is let go, as it is then set free from the force that binds it to the circle.* On the other hand, if the projectile or centrifugal force were suspended, the earth would fall to the sun. But being perfectly surrendered to the joint influence of the two different forces, the earth is constantly deflected by their regulated strife from the straight lines A B and A S, and pursues a curvilinear path, as the result of their combined action. Thus without iron trackways to define their course, or bars and bolts to keep them in place, the planets are securely poised in space, move freely through it in vast orbits round the sun, and accomplish with unerring certainty their respective cycles. "The Lord by wisdom hath founded the earth; by understanding hath he established the heavens."

The demonstrations of Newton were published in the "Principia," in the year 1687, under the auspices of the Royal Society, but at his own expense. The name implies that the work contains the fundamental principles of natural philosophy. It is divided into

three books. The first treats of motion in free space; the second is chiefly occupied with questions relating to resisted motion; and the third is upon the system of the world, by which is to be understood, the arrangement of all the bodies that compose the material universe, with their relations to each other, now commonly denoted by the phrase, the "mechanism of the heavens." During the two years that the illustrious author was engaged in preparing his work, he seemed to live only to calculate and think, often acted unconsciously, took no cognizance of the ordinary concerns of life, and had to be reminded by others of the time of his meals. The volume, upon its first appearance, was read with admiration by the leading mathematicians of the day among his own countrymen; and its doctrines were soon taught at all the universities. On the continent, the theory of gravitation was generally rejected for at least half a century. But the hour of universal triumph came at last; and finely has the truth of its principles been illustrated by foreign geometers, while they have cheerfully recognised Newton as the Father of Physical Astronomy. Yet though one of the most eminent of them has assigned to the Principia the pre-eminence over all the other productions of the human intellect, its author, when receiving on one occasion the compliments of his friends, thus reviewed his career:—"I know not what the world will think of my labours, but to myself it seems to me that I have been but as a child playing upon the sea-shore, now finding some pebble rather more polished, and now some shell rather more agreeably variegated than another, while the immense ocean of truth extended itself unexplored before me."

At the advanced age of eighty-five, Newton died in

London on the 20th of March 1727, having long enjoyed the honours due to his exalted genius, and been furnished with the means of acquiring considerable wealth. All through life he recognised the primary importance of religion, especially the claims of revealed religion, and the paramount authority of the word of God. Towards the close of his days, when an invalid, he read much; and the book which was commonly lying before him, and to which he most frequently turned at last, was a duodecimo Bible. His death was deplored as a national loss; and his obsequies were celebrated with peculiar distinction. The body, after lying in state in the Jerusalem Chamber, was interred in Westminster Abbey, six peers bearing the pall. A Latin inscription on the monument that marks the grave closes with the sentence—"Let mortals congratulate themselves that so great an ornament of the human race has existed." The Royal Society of London possesses his telescope; the Royal Society of Edinburgh the door of his book-case; and Trinity College, Cambridge, has a lock of his silver white hair.

While Newton completely established the existence of the principle of gravitation, succeeding physical astronomers have more fully developed its consequences, and unfolded its empire, successfully applying it to phenomena beyond the bounds of our system, as to *the binary and multiple schemes* of stars, which the powerful telescopes of modern date have discovered. They have also demonstrated, that under its rule, stability and permanence are consistent with constant perturbation and incessant change. As each of the worlds around us exerts an influence upon all the others, planet swaying planet, and satellite bending to

satellite, their orbits are not invariable, but slowly rock to and fro, contracting and expanding, as the effect of their mutual attraction. Hence, at first sight, nothing seems more probable, than that such disturbances may lead eventually, by accumulation, to the destruction of the system. But it has been placed beyond a doubt, that every irregularity in the motion of the planets, and in the form of their orbits, is periodical; in other words, the inequality has its assigned limits, beyond which it can never pass: so that, after reaching its maximum, it will diminish according to the same law by which it increased. Ever since the date of the earliest astronomical observations, the orbit of the earth has been slowly losing its eccentricity, and changing from an ellipse into a circle, thereby accelerating the mean motion of the moon. But after a certain cycle, this change, by virtue of the same cause that produces it, will be corrected, and the orbit gradually return to its former ellipticity, the moon's motion being proportionally retarded. In a similar manner, all the planets experience perturbations, which oscillate through long cycles of time within definite limits, having a bound set to them by a "perpetual decree." There is thus no chance-work or faulty architecture in the construction of our mighty system; neither has it been arranged upon the principle of self-destruction. It is not wearing itself out. The great Machinist is ever with the work of his own hands, observing and directing every motion; and whenever an end shall come to the present constitution of things, it will not be the result of nature's decay or disorder, but of the fiat of the Almighty.

CHAPTER III.

THE GREATER LIGHT.

Distance of the Sun—Mean Distance—Solar Diameter—Circumference—Volumes and Masses of the Sun and the Earth—Results—Solar Rotation—Spots observed by the Naked Eye—Early Telescopic Observations—Appearances caused by the Solar Rotation—Rapid changes of the Spots—Their Magnitude—Nucleus and Penumbra—Bright Spots—Theory of Wilson—Views of Herschel—Habitability of the Sun—The Sunbeam—Light—Theories of Light—Velocity of its Transmission—Analysis of the Sunbeam—Importance of the Luminous Principle—Influence on Vegetation—The Solar Heat—Chemical Rays—Zodiacal Light—Blessings of the Light.

The Sun, "the light that rules the day," is a self-radiant spheroid of matchless splendour, the mighty ruler, and animating principle of a group of circumvolving worlds, seated at the centre; for the farthest member of the planetary system is, equally with the nearest, directed in its movements, and maintained in its orbit, by the force of the solar attraction. The grand luminary has dimensions in accordance with this supremacy of aspect, position, and office; but appears only as a small circlet in the firmament, owing to the vastness of its distance from the terrestrial spectator. By careful computations, chiefly based upon observations of the transits of Venus, it has been found that the sun's mean distance from the earth is, in round numbers, ninety-five millions of miles; and this conclusion is supposed to involve no inaccuracy greater than [illegible]th part of the whole. Though light travels across the mighty gulf in eight minutes, yet with any velocity which we can create, it would require a long interval of time to make the passage. A cannon ball, retaining through-

out its full force, would be about seven years in effecting it; and a railway train, moving incessantly thirty miles an hour, would be three centuries and a half on the route. To the uninstructed, it appears marvellous in the extreme, and scarcely credible, that the distances of the heavenly bodies, with their magnitudes and velocities, can be calculated with any degree of exactness. But those who cannot fully understand the way in which such problems are solved, may be convinced of their accuracy and truth, by remembering the precision with which eclipses, occultations, and transits are predicted. The remark may be added, that nothing is more common in surveying countries, and conducting siege operations, than for the distance of terrestrial objects to be determined, without traversing the intervening ground; and the measurement of distances in the heavens depends on the same infallible geometry.

The *mean* distance of the sun supposes a greater and a less. There would be no variation if the earth described a perfect circle in the course of its annual revolution. But moving in an elliptical orbit, it is nearer the sun at one point by about three millions of miles than at another. An interval of six months elapses between the two extremes; and the mean distance is a balance struck between them. This periodic variation of distance is manifested by a slight difference in the apparent magnitude of the solar globe. When the earth is at its nearest point to the sun, the latter has an apparent diameter of 32′ 35″·6, which is reduced to 31′ 30″, at an opposite season, when most remote. It may here be stated, that the sun's apparent diameter at any given time is the same, whether measured in the horizontal or vertical direction, except when near the horizon. Then the disk occasionally

exhibits an oval form, owing to the rays of light from the upper and lower limbs being unequally refracted in passing through the atmosphere. Intelligently have the foundations of the earth been laid, at such a distance from the source of light and heat, as is exactly suited to the organized forms upon its surface. If much nearer or more remote, animals and plants would perish, without some change of constitution, owing to increased heat or cold; and the blaze of light would be insufferable, or its amount too small to serve the purposes of vision.

It is obvious that a body must be of stupendous size to form such a conspicuous circle in the heavens as the sun, while at the distance of nearly a hundred millions of miles from us. The sun's diameter is not less than 882,000 miles, or rather more than one hundred and eleven times the diameter of the earth. It is difficult to conceive aright of this enormous magnitude; but it may be illustrated by the statement that the solar globe would fill up the entire orbit of the moon, and stretch beyond it more than two hundred thousand miles in every direction. Were the sun a hollow sphere perforated by a thousand openings to admit the twinkling of the luminous atmosphere without, then a globe as large as our own might be placed at the centre, with a satellite as large as the moon, and at the same distance from it as she is from the earth, and there would be present to the eye of the spectator, on the interior globe, a universe as extensive as the whole creation was conceived to be in the infancy of astronomy, and as splendid as the heavens appear at present to the uninstructed gazer. Supposing the earth to be represented by a ball of one inch in diameter, another of nine feet four inches would represent the size of the sun. The loftiest of the earth's

mountains, one of the Himalayas, rises to the height of 29,000 feet, and for a mountain to rise upon the solar surface, bearing the same proportion to the solar diameter as the Himalayan peak to the terrestrial, it would require to have an altitude of nearly six hundred miles.

The great orb has a circumference of 2,646,000 miles, in comparison with which, that of our own globe, twenty-five thousand miles, is quite insignificant. If it were possible for a railway carriage to go round the earth at the rate of thirty miles an hour, the journey would be accomplished in five weeks, travelling night and day; but a similar journey would require upwards of ten years on the surface of the sun. The solar volume, or bulk, is 1,400,000 times greater than that of the earth; and exceeds five hundred times the aggregate bulk of all the bodies of the planetary system. In other words, one million four hundred thousand earths must be rolled together, and the united volumes of all the planets and satellites be multiplied five hundred times, in order to form a body of equal size to the one sun. The quantities here given afford an overpowering view of magnitude.

The substance of this splendid body, of whatever it may be composed, is widely different from that of our own planet, for while their respective volumes are in the ratio of 1,400,000 to 1, their respective masses or weights are in the ratio of only 355,000 to 1. The latter ratio is about four times less than the former. Hence the density of the matter of the sun must be four times less than that of the earth, or, bulk for bulk, the sun is four times lighter. While, therefore, it would take 1,400,000 terrestrial worlds to equal the sun in volume, it would require only about one-fourth of the number, or 355,000, to make the balance even be-

tween them as to their amount of ponderable matter. Upon the mass or weight of each planet, the weight of bodies at its surface mainly depends, for weight is only the pressure due to intrinsic gravitation. Though the sun is, volume for volume, so much less dense or lighter than the earth, yet, owing to its enormously superior mass, such is the force with which gravitation acts at its surface, that a body weighing one pound at the terrestrial equator, would weigh twenty-nine pounds if removed to the equator of the sun. A man of ten stone in the one case would become a man of 290 stone in the other; and without a strengthened organization, he would be quite unable to sustain his own increased weight. This result, with others of a similar kind, rigidly deduced from mechanical laws, is calculated to rouse the mind to due ideas of the variety in the universe—a variety apparently commensurate with its vastness; and to exalt to the highest pitch our conceptions of the wisdom and potency of its Divine Author.

In common with all the planets, as far as their arrangements are known, the sun has a motion of rotation upon an axis, which is performed in the same direction as their axial movement, or from west to east. This has been ascertained by observation of the solar spots; and found to be accomplished in about twenty-five days and a half. The design of this motion is not so apparent as in the case of the earth and other planetary bodies. By their rotation, every part of their superficies is successively exposed to, and withdrawn from, the presence of the central orb; and they consequently experience the alternation of light and darkness, with the absorption and radiation of heat. But this reason will not apply to the sun itself, which is dependent upon no other body for these elements,

but dispenses them to the worlds which revolve around it. The rotation demonstrates the sphericity of the orb of day, and is the only clear proof we have of it; for it is within the limits of possibility, that a body always presenting the same face to us, might appear circular in that one aspect, and not be so in reality. Since the circular appearance of the sun is invariable. while by its rotation every part of the surface is exposed to the eye, its form must be globular.

The ancients regarded the sun's disk as immaculate and immutable; and it is occasionally clear through considerable intervals. But there are several well-attested instances on record of peculiarities being observed contradicting this ancient fancy; and as soon as the age of telescopic observation commenced, its fallacy was at once demonstrated. Thus Adelmus, a Benedictine monk, who wrote a life of Charlemagne, mentions a black spot appearing upon the sun in the year 807, on the 16th of the calends of April, or March the 17th; and Bede and other historians record the same circumstance. Averroes, a Spanish Moor, in his commentary on the Almagest, towards the middle of the twelfth century, affirms that he saw two dark spots on the sun. In the second voyage of James Welsh to Benin, in 1590, recorded in Hakluyt, it is stated, that early in December of that year, the good ship "Richard of Arundel" had arrived off the coast of Guinea, when the following entry was made in the log:—"The 7th, at sunset, we saw a great black spot on the sun; and on the 8th, both at rising and setting, we saw the like, the spot appearing about the size of a shilling." It was seen again on the 16th. Galileo mentions an immense spot which appeared on the centre of the sun's disk, which he, as well as many

others to whom he showed it, was enabled to perceive with the naked eye, at sunset in August 1612. Mysterious diminutions of the solar light have also been noticed, without any concurrent eclipse to explain the phenomenon. Plutarch tells us, that in the first year of the reign of Augustus, the sun's light was so greatly diminished, that it might be gazed at without inconvenience. Abulpharagius relates, that in the ninth year of Justinian a similar obscuration occurred, and also in the seventeenth year of Heraclius. Kepler states, that in 1547, the same day on which the battle of Mühlberg was fought, the sun appeared reddish, as when viewed through a thick mist, and the stars were visible at midday. It has been suggested, to account for such phenomena, that there might be a temporary accumulation of spots upon a scale sufficiently great to impair sensibly the solar radiance. Though this may be very doubtful, it is clear that spots had been observed before the use of the telescope.

Galileo, Fabricius, Scheiner, and our own countryman Harriot, were the first to whom the telescope distinctly revealed dark specks and patches on the face of the sun. Their observations were made independently in the year 1611. Yet such confidence was placed in the old dogma concerning the sun's purity, that many denied the existence of such blemishes; and they were alleged to be either planets revolving at small distances from its surface, or spurious phenomena, arising from impurities in the glasses used. Upon Scheiner, a German Jesuit, reporting the evidence of his senses to his provincial superior, the latter positively refused to believe him. "I have read," said he, "Aristotle's writings from end to end many times, and I can assure you that I have nowhere found in them

anything similar to what you mention. Go, my son, and tranquillize yourself: be assured that what you take for spots in the sun are the fault of your glasses, or your eyes." Such appearances are now familiar, for they may be seen with a telescope of very low power, and occasionally with the naked eye. But great caution is requisite in telescopic observations of the sun, owing to the intense glare. The loss of an eye, or serious injury to the sight, has been caused by inadvertently neglecting to use a coloured glass, or to reduce the aperture of the instrument.

The following are some general results of observation upon these peculiarities. The spots, or *maculæ*, as they are called, are not stationary, but have a common motion on the solar disk. This was one of the first facts noticed; and it irresistibly led to the conclusion, that the sun has a rotatory motion on a fixed axis. As they advance from the eastern limb or edge, and become central, their appearance alters, gradually expanding; and on receding from the centre to the western edge, it as gradually contracts. They seem also to move with greater velocity over the central parts than when advancing to or receding from them. But these are obviously optical illusions, caused by our oblique view of the marginal parts of the sun's disk. The time occupied in the transit from the eastern to the western limb is somewhat less than a fortnight; and after a similar interval the same spot has been recognised again at the eastern edge, recommencing its passage. It is a well-ascertained fact, that the spots are confined, for the most part, to the equatorial regions of the sun, or to a zone extending to about 35° north and south of the equator, called by Scheiner the "royal zone."

While some spots remain visible for a considerable interval, and make successive passages over the sun before they entirely vanish, others have a very brief duration, and sometimes disappear in a remarkably abrupt and sudden manner. Sir W. Herschel states, that while engaged in observing a spot on the 19th of February 1800, he fixed his attention on several places, but on looking off, even for a moment, they could not be found again; and Sir John Lubbock remarks, that he has observed spots so large as to be visible to the naked eye, of which, on the following day, not a trace could be distinguished, even with the aid of a good telescope. Great differences are noticed as to shape and magnitude, from minute black specks to irregular patches of enormous dimensions. In 1754, Mayer perceived a spot extending to one-twentieth of the sun's apparent diameter, which is equal to an absolute diameter of about 44,000 miles. Herschel also, in 1779, remarked one with the naked eye, which, on observing with a telescope of high magnifying power, he found to be divided into two parts; and the larger portion indicated an absolute length of 31,000 miles. The conjecture has been entertained, but is not at all supported by evidence, that unusually large or numerous spots have an effect in depressing the temperature of the terrestrial seasons.

An important characteristic of the solar spots, first noticed by Scheiner, is the difference in shade between the central tracts and the borders. Intense blackness distinguishes the central part, termed the *nucleus;* but it is surrounded on all sides by a definite belt shaded with less intensity, called the *penumbra,* of nearly uniform obscurity. The nucleus and penumbra do not gradually pass into each other, but are separated by

a well-defined boundary; and the penumbra is generally distinguished from the luminous surface of the sun by a very distinct bounding-line. Interesting appearances of an opposite character on the solar disk have also been disclosed, or parts of the surface more resplendent than the surrounding regions, hence called *faculæ*. These bright tracts are transitory. They are sometimes round, but commonly have the form of waves or ridges, and are chiefly seen in the neighbourhood of the black spots. When they appear alone, it is almost invariably as the precursors of spots visible a day or two afterwards. It has also been ascertained, that the whole surface of the sun is diversified with minute bright specks and small black pores—phenomena which are found to be in a state of constant change. They give to the disk a mottled and corrugated appearance, comparable to the roughness of the skin of an orange.

The spots have been viewed as dark smoke and scoriæ floating on the abyss of combustion, which the sun has been conceived to be, while the indications of superior splendour have been referred to volcanic eruptions of the fused mass. Still more unauthorized and far wilder speculations have been indulged. A sober theory, supported by reasoning of a purely inductive character, was first propounded by Dr. Wilson of Glasgow, in the year 1773. He maintained that the sun is an opaque mass surrounded by a luminous atmosphere; and that the spots are excavations or rents in this outer splendour, by means of which the observer is enabled to see the dark body of the sun itself. According to this view, the nucleus of a spot is the bottom of the excavation, and the penumbra the

sloping sides. All succeeding observations have confirmed this supposition; and it may be deemed strictly demonstrated, that the spots are depressions below the level of the rest of the solar surface. But while the hypothesis satisfactorily accounts for the black nucleus, it does not explain the striking difference in aspect between the less-shaded penumbra, and the luminous region around it. Sir W. Herschel therefore supposed the sun to be surrounded by two distinct envelopes at different elevations—the one, an upper or outer stratum of self-luminous clouds, constituting the source of light and heat; and the other, a lower or inner stratum of opaque clouds, which shine only by the reflection of the brilliant regions above them. In these strata the spots are held to be openings, which reveal the solid globe of the sun, forming the dark central part, or nucleus. The surrounding penumbra is referred to the lower stratum of dense clouds; and the *faculæ*, or bright ridges, in the neighbourhood of the depressions, are accumulations of the luminous matter of the exterior stratum, heaped up as the consequence of the openings being formed.

The theory thus briefly described has obtained very general acceptance. It is sustained by appearances, and gives a consistent view of the solar spots; but it throws no light upon the physical cause of these remarkable features. Yet indications are afforded that they are produced by circulating movements in a gaseous atmosphere around the sun, which the solar rotation may call into action, just as the rotation of the earth upon its axis gives birth to our system of trade winds. "The spots, in this view of the subject," says Sir John Herschel, referring also to their equatorial

position, "would come to be assimilated to those regions on the earth's surface, in which, for the moment, hurricanes and tornadoes prevail."

This view of the solar constitution led its author to believe that the solid body of the sun may experience only a moderate temperature, being effectually screened by the lower stratum of dense clouds from the fiery blaze of the upper, the fountain of light and heat to the far-outlying planetary worlds. He conceived of it therefore as a globe fitted to accommodate organized beings; and many distinguished men have subsequently adhered to the same opinion. It is remarkable, that just before the elder Herschel gave the authority of his great name to the doctrine of the sun being probably a habitable globe, the same idea exposed another person to the imputation of insanity. Dr. Elliott, the person referred to, sent a paper to the Royal Society, in which he maintained that "the light of the sun proceeds from a dense and universal aurora, which may afford ample light to the inhabitants of the surface beneath, and yet be at such a distance aloft as not to annoy them"—that "vegetation may obtain there as well as with us"—that "there may be water and dry land there, hills and dales, rain and fair weather"—and that, "as the light and the seasons must be eternal, the sun may easily be conceived to be by far the most blissful habitation of the whole system." But so extravagant were these views deemed, that they were quoted against him in a court of justice as a proof of his insanity; and yet, in less than two years afterwards, Sir William Herschel, the most sober, pains-taking, and accomplished physical inquirer of his age, deemed the conception rational and probable, as deduced from his own observations on the solar constitution. This is a point upon which

no dogmatic opinion can be pronounced either way. All that we know with absolute certainty is, that the bountiful Creator, in his infinite power and resources, can readily accommodate productions to circumstances and conditions apparently to us the most adverse to existence; and that, could we take a giant stride to the sun, we should have occasion to say, "Surely the Lord is in this place." "The fulness of Him that filleth all in all" fills it, whether the solid sphere be seven times hotter than a burning fiery furnace, and intolerably brilliant, or black as midnight and cold as death; and the same reason applies there as here, why the psalmist's reflection should be entertained—"Whither shall I go from thy Spirit? or whither shall I flee from thy presence?"

Wholly independent of the question, whether the sun is the abode of organized and sentient life, it fulfils an illustrious vocation, retaining the planets in their spheres, and extends to them the genial influence of the sunbeam, which, at least on the earth, quickens vegetation, produces daylight, paints the sky, gives the gleamings on the rivers, the lustre and beauty of flowers and woods, of grassy fields and heathery hills.

The sun is the centre and source of many influences, three of which are distinctly recognised, and may be separated from each other—light, heat, and chemical force. Each of these may be briefly noticed.

If, after having been manifested to the senses of men for six thousand years, unveiling the home landscape and the far-off sublimities of the creation, and winning universal homage to the sentiment so beautifully expressed by the royal teacher, "Truly the light is sweet, and a pleasant thing it is for the eyes to behold the sun," the nature of the grand element still remains enigmati-

cal, a large amount of knowledge has been acquired respecting its properties and connexions of the highest interest and utility. An endless series of beneficial phenomena depend upon the natural agent; and its importance is empathically declared by the magnificent command inaugurating its visible activity in the present cycle of terrestrial history—" Let there be light: and there was light." Not less significant of value is its consecration by inspired authority as the symbol of Divinity, and the emblem of the condition of humanity glorified.

Two theories have chiefly divided the scientific world respecting the nature and propagation of light—the undulatory and the corpuscular. The former had precedence of the latter, but was almost completely supplanted by it for upwards of a century, when it was revived in 1801, and has gradually obtained the ascendency. The corpuscular hypothesis supposes light to consist of excessively minute material particles projected from luminous bodies, the sun, fixed stars, and incandescent substances. To this it has been objected, that no sensible diminution has been observed of the solar volume since the epoch of observation commenced, notwithstanding the presumed incessant projection of luminous particles from every part of the surface. The undulatory hypothesis supposes a highly-attenuated medium, or ether, to pervade all space, so rare as not to offer perceptible resistance to the movements of the planets, and not to be cognizable to our senses while at rest, light resulting from luminous bodies setting its particles in motion, propagating waves or vibrations through it in all directions, as sonorous bodies propagate vibrations through the atmosphere, conveying sound. The theory of projection, while more open to

popular apprehension, and affording an easy and intelligible explanation of many observed facts, completely fails to account for many others. On the other hand, the theory of undulation, though less apparently natural, and not so readily embraced by the mind, explains so thoroughly a great variety of intricate phenomena of light, as to have received the sanction of the great majority of modern philosophers. Sir J. Herschel has styled it, in allusion to its facility of explanation, "one succession of felicities," and even if it were not true, "one of the happiest fictions that the genius of man has yet invented."

Both theories recognise conclusions founded upon the prodigious velocity with which light is transmitted —a fact resting on sensible evidence—which are astonishing even to those who are accustomed to contemplate the power of natural agencies. That time is required for its propagation in space was first shown by observation of the eclipses of Jupiter's satellites taking place sooner or later, according as the earth is at its least or greatest distance from the planet. The difference of time is sixteen minutes; and the difference of distance the diameter of the earth's orbit, or 190 millions of miles. Light, therefore, whether viewed as a projection or an undulation, occupies that time in travelling over the space in question which gives it a velocity of 192,000 miles per second. This has been confirmed by subsequent accurate astronomical determinations, based upon different data. The greatest average velocity of ponderable matter with which we are acquainted—that of Mercury in his orbit—does not much exceed thirty miles a second, which only amounts to $\frac{1}{6000}$th of that of light. Owing to the enormous rapidity of transmission, luminous objects at the

surface of the earth—a rocket or a signal fire—are seen at the same moment by spectators, however their relative distances may differ, fifty, a hundred, or a thousand miles being traversed in perfectly inappreciable time.

It follows from this wonderful velocity, adopting the corpuscular theory, that the luminous particles must have an inconceivable minuteness, for it has been calculated that a molecule having the sensible magnitude and weight of a single grain would be equal in its effect, owing to its momentum, to a cannon-ball of 150 lbs. discharged at the rate of a thousand feet a second. In this case, what is now the agent of so much good to man would be the instrument of his destruction, meeting the organs of vision like a charge of shot from the barrel of a gun, and the globe he inhabits would as surely perish as a house of clay under the action of a park of artillery. But no sensible effect has ever been produced upon the most delicate apparatus by millions of molecules concentrated by mirrors, and lenses at a single point. How utterly beyond conception, therefore, the tenuity of the component parts? The other theory involves almost equally overwhelming results, in the excessive smallness and astounding frequency of the ethereal vibrations. As light moves at the rate of 200,000 miles a second, using round numbers, it follows, that a length of ray amounting to 200,000 miles must every second enter the pupil of the eye, and that the retina must vibrate the same number of times as there are luminous waves or undulations in the ray. Now, 200,000 miles contain 12,000,000,000 inches; and in the case of violet light, it is calculated that there are 59,000 waves in each inch. This gives upwards of 700,000,000,000,000

waves for the whole length of the ray; and as the ray enters the eye in one second, the retina trembles at that rate per second, when we are gazing upon a violet object.

From Newton's analysis of the sunlight, admitted into a dark chamber through a hole in the window-shutter, and subjected to a prism, he inferred white light to be a compound of seven differently-coloured beams, called colorific and primary, because each single beam was incapable of separation by the prism. These tints of the solar spectrum—red, orange, yellow, green, blue, indigo, and violet—are finely expressed by the pencil of nature in the rainbow. Newton's analysis of the sunbeam has been shown to be imperfect, for the seven colours result from three primary ones, the red, the yellow, and the blue, interposed variously in different parts of the spectrum. That endless variety and combination of tints displayed by the flowers of the field, the rich hues of autumnal woods, and the gorgeous plumage of tropical birds—in short, the colours of all objects, whether opaque bodies or transparent media, arise from their varying capacity of absorbing or reflecting certain rays. Thus light is the great beautifier of nature, both inorganic, animal, and vegetable; and truly did the Divine Saviour remark of the flowers of the field, that "Solomon in all his glory was not arrayed like one of these."

The potent influence of the purely luminous principle in the solar beam upon vegetation is strikingly signified by the *etiolation*, or blanching, of plants by covering them up from the light. The effect is intentionally produced by the market-gardener to render certain vegetables more palatable, by checking those secretions which cause rankness in natural conditions. Humboldt beheld with astonishment the progress of

subterranean vegetation in the Cueva del Guacharo, an immense longitudinal cavern in the district of Caraccas, inhabited by nocturnal frugivorous birds. Seeds carried in by the birds to their young, and dropped, had sprung up, producing tall, blanched, spectral stalks. covered with half-formed leaves; but it was impossible to recognise the species from the change in form, colour, and aspect, which the absence of light had occasioned. The native Indians gazed upon these traces of organization in darkness with mingled curiosity and fear, as if pale and disfigured phantoms banished from the face of the earth. The traveller remarks, "They recalled one of the happiest periods of my earliest youth—a long abode in the mines of Freiberg, where I made many experiments on the effects of blanching."

No plant grown in the dark is green; but the peculiar substance called chlorophyll, upon which the green colour depends, immediately begins to be generated in the cells upon exposure to the light. The vast forests of the Amazon and Orinoco frequently exhibit on a grand scale the influence of light in colouring when the leaf-buds are developing. Clouds and rain sometimes obscure the atmosphere for several days together, and during this time the buds expand themselves into leaves. But these leaves have a pallid hue till the sun appears, when, in a few hours of clear sky and splendid sunshine, their colour is changed to a vivid green. It has been related, that during twenty days of dark dull weather, the sun not once making his appearance, the leaves were expanded to their full size, but were almost white. One forenoon the sun began to shine in full brightness, when the colour of the forest changed so rapidly that its progress might be

marked. By the middle of the afternoon, the whole, for many miles, presented the usual summer dress. The instinct of plants is very remarkable, or the sensible indications afforded of their dependence upon the luminous element. The stately head of the annual sun-flower moves with the sun from east to west, returning by natural elasticity after sunset to the east, to meet the solar beams in the morning; the innumerable leaves of a clover-field follow the same course; and all plants, more or less, pay the same deference to sunlight. Those of the hothouse will direct their branches to the side where it is most copious, and not to the quarter of the heated flue, or where the most air is admitted.

Further analysis of the solar beam has unveiled an additional phenomenon, that of calorific or heat-exciting rays, distinct from the luminous. Equally as influential and benign is their agency in the realm of nature. The evidence of this is at once supplied by the contrast everywhere between summer and winter, and the different scenery of the equator and the poles. But besides contributing to the direct development of life in the animal and vegetable kingdoms, the calorific rays produce a variety of remarkable effects upon the inorganic creation, without which this could not be a habitable world. The sun warms the earth; the earth imparts its warmth to the overlying air; the warmed air expands, becomes lighter, and rises; and a current of colder air at once proceeds to take its place, to experience the same change. Thus the winds are put in motion to freshen the atmosphere, maintain its salubrity by preserving the due admixture of its components, and enable the mariner to sail across the deep. By the agency, also, of the solar heat, aqueous particles

are exhaled from the ocean, lakes, rivers, and moist earth, from which we have clouds,—reservoirs of water in the air,—finally discharging their contents upon the land in fertilizing showers of rain or snow. Such is the heating power of the solar rays, that some of the men employed in the construction of the Plymouth Breakwater had their caps burnt in a diving-bell thirty feet under the surface of the sea, from inadvertently sitting under the focal point of the convex glasses in the upper part of the machine.

Distinct from the luminous and heating principles in the sunbeam, there are the chemical rays, which excite neither light nor heat, but speedily produce peculiar changes in certain substances exposed to their action, as in the white chloride of silver, which is blackened in a few minutes on being placed in the sunshine. The apparently magical photographic processes by which true, delicate, and beautiful images are instantaneously produced, are founded upon the action of the chemical rays; and the diversities of complexion which distinguish the human race—the copper of the Indian, and the ebony of the negro, appear to be chiefly due to their influence. In fact, the entire surface of the earth, with all its plants and animals—the granite rock which meets with firmness the driving storm; the stones which form the "cloud-capt towers and gorgeous palaces" of the architect; the marble which the artist chisels into life-like memorials of departed greatness—are all acted upon, more or less, by the chemical and molecular disturbing power of the sunshine, and would all speedily perish if incessantly exposed to the delicate but potent touch of its beams. Hence darkness and rest, night and sleep, are needful for mountains and valleys, as well as for plants, animals, and man;

for science has determined, though it has not solved the mode, that, during those intervals, nature rectifies the chemical disturbances and molecular changes effected in the daytime. Therefore "the sun knoweth his going down. Thou makest darkness, and it is night. Man goeth forth unto his work and to his labour until the evening. O Lord, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches."

There remains to be noticed a singular and interesting, but mysterious appearance, accompanying the sun, long known under the name of the Zodiacal light, from its path lying obliquely in the zodiac. This is a glow, or beam of light, of a conical form, rounded at the vertex, and with the base at the horizon. Though usually faint and white, it is sometimes bright and rosy, yet generally so transparent that the feeblest stars may be seen as distinctly through it as in other parts of the sky. In our latitude, in clear weather, it may be observed after sunset in the spring months, and before sunrise at the opposite season; but it is never so definite to us as it appears in tropical countries. Kepler noticed the zodiacal light; and from some intimations in Pliny it may be inferred not to have been unknown to the ancients. But it attracted little attention till the elder Cassini regularly described it in 1683. The nature of this object is perfectly obscure. It has been considered to be the solar atmosphere, receiving its peculiar form, that of a long narrow ellipse, only the half of which we can ever see, from the rotation of the sun upon its axis. But Sir John Herschel conceives it may be the denser part of that medium, which, there is reason to believe, resists the motions of comets loaded perhaps with the tails of

millions of those bodies, of which they have been stripped in their approach to the central orb, and which may be slowly subsiding to it.

Such is the sun,

> "Great source of day! best image here below
> Of the Creator."

Moses referred to the "precious fruits" brought forth by it when pronouncing the blessing of the tribe of Joseph; and in every age, as the early dawn has chased away the shades of night, the rudest nations have hailed the rising sun as in some manner intimately connected with the welfare of every object enjoying animal and vegetable life. This connexion, together with the ineffable glory, originated in unenlightened times the idolatry of the solar orb. Inspired wisdom teaches us to admire the material splendour, and to note its benefits, but to magnify the Divine hand in the formation of the wondrous globe. "The day is thine, the night also is thine: thou hast prepared the light and the sun." The position of the source of light and heat in the mechanism of nature is strikingly illustrative of intelligent and beneficial contrivance, for, obviously, the collection of the self-luminous matter in a vast mass at the centre of the solar system is the arrangement best adapted to secure the uniform, regular, and most liberal distribution of its influence through it. Hence, while we admire the all-pervading, bright, and life-sustaining sunbeam, and mark all nature rejoicing in its rays, while beautified to the eye by them, it is true philosophy, as well as true religion, to respond to the sentiment expressed in the psalmody of Israel:—"Oh give thanks unto the Lord;—to him that made great lights: the sun to rule the day: for his mercy endureth for ever."

CHAPTER IV.

MERCURY, VENUS, AND THEIR TRANSITS.

The Solar System – Inferior or Interior Planets – Sensible evidence of relative position – Mercury – Elements of the Planet – Difficulty of observation – First recorded Transit – Succeeding Transits – Lalande – Le Verrier and Mitchell – Venus – Elements of the Planet – Phases – First observed Transit – Youthful Astronomers of Lancashire and Yorkshire – Horrocks – Particulars respecting him – Predicts the Transit of 1639 – His Observation of it – His death – Memorials of Horrocks – Subsequent Transits – The Evening and Morning Star.

THAT portion of the universe of which the sun is the centre, as at present known, consists of eight principal planets revolving round it in the following order as to distance—Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune; twenty satellites attending these primary bodies, and circulating round them, of which the Earth has one, Jupiter four, Saturn eight, Uranus six, and Neptune one; fifty-five minor planets between the paths of Mars and Jupiter, also in revolution round the solar globe; and several comets, whose entire orbits are included within the planetary paths, besides hundreds of others which appear within the visible limits of the system, approach the sun, and retire from it into the depths of space. This makes a total of eighty-three planets and satellites, dependent upon, and controlled by, the attractive force of the central body. Of this number the ancients were only acquainted with six—the Moon, Mercury, Venus, Mars, Jupiter, and Saturn; and no more were known down to the commencement of the seventeenth century. Ten

were added between the years 1600 and 1700, namely, four satellites of Jupiter, five of Saturn, and the Earth itself, which had not previously been fully recognised as a planet. Nine were added between 1700 and 1800, namely, Uranus and six satellites, with two satellites of Saturn. The remaining fifty-eight bodies, consisting of the minor planets, a satellite of Saturn, Neptune and a satellite, have all been discovered since the beginning of the present century, and, with the exception of four, since the year 1845. These orbs revolving round a common centre, and mutually influencing each other, form a group—the solar system—the family of worlds to which we belong. It may be considered as a compact section of the creation, for though its components are separated by distances which are enormous, in relation to ordinary terrestrial standards, they are comparatively close, in contrast with the immense chasm which intervenes between the remotest planet and the nearest member of the stellar universe. We have the word planet from πλανήτης (*planetes*) "a wanderer," in allusion to apparently erratic movements; and satellite, from *satelles* "an attendant," referring to a companion orb.

The great planets are never seen far in the north, or in the south, since they are always near the ecliptic, or the grand highway in which the sun appears annually to travel among the stars. They never diverge out of a zone or girdle, extending a few degrees on each side of this circle, called the zodiac; but several of the minor planets make wide excursions beyond it, and are hence called *extra-zodiacal*. Mercury and Venus have their orbits nearer the sun than that of the Earth, and are called *inferior* planets, while all the others are farther from the sun than the earth, and are grouped as

superior. Sensible evidence is afforded of the relative position of the planets as interior or exterior to each other. Thus Mercury and Venus are never seen far apart from the sun, and are therefore only observed by the naked eye for an interval after sunset and before sunrise; whereas the rest appear in opposition to the sun, rising in the east at sunset, setting in the west at sunrise, shining aloft at midnight, and occupying all intermediate points. Sometimes, although very rarely, the relative neighbourhood to us of two planets is declared by an occultation, the one passing over the other. Kepler states, that on the 9th of January 1591, Mæstlin and himself witnessed an occultation of Jupiter by Mars, when the red light of the latter plainly indicated his being the nearer of the two to the earth. He also mentions, that on the 3rd of October 1590, Mæstlin witnessed an occultation of Mars by Venus; and on this occasion the white colour of Venus afforded a clear proof of her interior position. In a similar manner Venus has been observed to occult Mercury.

MERCURY.

This planet, the nearest to the sun, as far as we know, is the swiftest and the densest body in the system, also the smallest of the primary class, and has the shortest period of revolution. His mean distance from the sun is thirty-six millions of miles; and in eighty-eight of our days he sweeps round the solar globe, travelling at the enormous rate of more than a hundred thousand miles an hour. The period mentioned, equal to nearly three months, constitutes his year; and if there are seasons, observing the same proportions as with us, each will accomplish its course in three weeks. The planet has a diameter estimated at 3140 miles, which falls consi-

derably short of the semi-diameter of the earth. A rotation upon an axis in rather more than twenty-four hours, a spheroidal form, with the exhibition of phases corresponding to those of the moon, and indications of a dense atmosphere, are other known particulars.

Mercury has given more trouble to astronomers than any other member of the system, for, owing to his proximity to the sun, he is usually lost in the solar glory, and is never seen in a dark part of the heavens, even at the time of his greatest distance. This circumstance, together with a small mass, and an immense velocity, renders it difficult to catch and watch him. In high latitudes, where the twilight is strong and lengthened, while mists often overhang the horizon, the planet can seldom be seen with the naked eye. Hence an old astro-meteorologist contemptuously describes him as "a squirting lacquey of the sun, who seldom shows his head in these parts, as if he was in debt." Copernicus lamented that he had never been able to obtain a sight of Mercury; and the French astronomer Delambre only saw him twice with the naked eye. The most favourable times for observation are about an hour and three quarters before sunrise in autumn, and after sunset in spring; but very clear weather and a good eye are required. At certain periods, when between the earth and the sun, on a line joining the centres of the two bodies, Mercury appears projected on the solar disk as a small round dark spot. This is called a *transit*, and would occur during every revolution if the plane of his orbit coincided with that of the orbit of the earth. But as one half of his orbit is a little above that of the earth, and the other half a little below it, he passes above or below the sun to the terrestrial spectator, except at those intervals, when, being

between us and the sun, he is also at one of the two *opposite points where the planes of the respective orbits intersect each other. Then, stripped of all lustre, the planet passes over the face of the great luminary as a black circular speck, affording evidence of his shining by reflected light, and of his spherical form.*

The first transit of Mercury recorded in history was predicted by Kepler, and witnessed by Gassendi, at Paris, on the morning of a cloudy day, the 7th of November, 1631. It was towards nine o'clock when he saw the planet; but owing to its extreme smallness, he was at first inclined to think it was a minute solar spot. It was then going off the sun; and made its final egress towards half past ten. The observed time of the transit was nearly five hours in advance of the computed time. This was a very satisfactory accordance for that age between theory and observation; but it was the effect of a fortuitous combination of circumstances, rather than of computations founded upon well-established data. "The crafty god," wrote Gassendi, in the peculiar style of his day, "had sought to deceive astronomers by passing over the sun a little earlier than was expected, and had drawn a veil of dark clouds over the earth in order to make his escape more effectual. But Apollo, knowing his knavish tricks from his infancy, would not allow him to pass altogether unnoticed. To be brief, I have been more fortunate than those hunters after Mercury who have sought the cunning god in the sun. I found him out, and saw him, where no one else had hitherto seen him."

The second observed transit took place on November 3rd, 1651. On this occasion, Shakerley, a young Englishman, having found by calculation that it

would only be visible in Asia, made the voyage to India, and witnessed it at Surat. The third recorded instance *occurred on the 3rd of May, 1661, the day of the coronation of Charles II. Amid the hurly-burly of the Restoration, the transit was watched in London by* Huyghens, Street, and Mercator, who are said to have made their observations in Long Acre, then a field, with an excellent telescope. Hevelius also saw it at Dantzic; but so little dependence could then be placed upon the tables of the planet, that he and his assistants were kept four days at their telescopes, waiting for the phenomenon, lest it should escape them. The fourth transit, on the 7th of November, 1667, had a competent witness in Halley, who was then residing at St. Helena, on an astronomical mission; and he was the first who observed both the ingress and egress of the planet. Succeeding transits have been chiefly interesting for the greater accuracy with which the times have been computed; but through the whole of the last century the errors frequently amounted to several hours. In 1786, Lalande, at Paris, was greatly disappointed because Mercury appeared on the sun's disk three quarters of an hour later than the time he had fixed for it, and three quarters of an hour earlier than that assigned by the tables of Halley. But Lalande lived to attain greater precision; and witnessed with delight a transit on the 8th of November, 1802, which more exactly answered to his calculations. "The passage of Mercury over the sun's disk," he states, "was observed this morning for the nineteenth time. The weather was exceedingly favourable, and astronomers enjoyed in the completest manner the sight of this curious phenomenon. I was the more anxious to have a view of it, as I shall never see it more."

After discrepancy between theory and observation as to the times of contact had been reduced to about a minute and a half, Le Verrier, the great geometer of France, took the planet in hand, in the year 1844. He profoundly examined the recorded movements of Mercury, calculated all the terms of perturbation, and deduced a new set of tables, from which his places are predicted with wonderful precision. A transit in the following year, May 8, 1845, was eagerly anticipated as a test of the accuracy of the young astronomer. But all observation in Paris was rendered impossible by the clouds which covered the sky through the entire day. While the computer was thus sadly disappointed, Mr. Mitchell, of the recently-founded observatory in Cincinnati, in the United States, was more fortunate in having to deal with a pure and transparent atmosphere. "For three years," he remarks, "I had been toiling to complete a most difficult and laborious enterprise, the erection of an astronomical observatory of the first class, in a country where none had ever existed. Amid difficulties and perplexities which none can ever know, the work had moved on; and at length I had the high satisfaction of seeing mounted one of the largest and most perfect instruments in the world. I had arranged and adjusted its complex machinery, had computed the exact point on the sun's disk where the planet ought to make its first contact, had determined the instant of contact by the old tables, and by the new ones of Le Verrier, and with feelings which must be experienced to be realized, five minutes before the computed time of contact, I took my post at the telescope to watch the coming of the expected planet. After waiting what seemed almost an age, I called to my friend how much time was yet to pass, and I found

but one single minute out of five had rolled heavily away. The watch was again resumed. Long and patiently did I hold my place, but again was forced to call out, 'How speeds the time?' and was answered that there were yet wanting two minutes of the computed time of contact. With stedfast eye and a throbbing heart, the vigil was resumed; and after waiting what seemed an age, I caught the dark break which the black body of the planet made upon the bright disk of the sun. 'Now,' I exclaimed, and within *sixteen seconds* of the computed time did the planet touch the solar disk, at the precise point at which theory had indicated the first contact would occur." Le Verrier was thus right to about sixteen ticks of the clock. The transits of Mercury during the remainder of the present century will be as follows:—

1861, Nov. 11.	1870, May 6.	1891, May 9.
1868, Nov. 4.	1881, Nov. 7.	1894. Nov. 10.

Those of 1881 and 1891 will not be visible in the north of Europe.

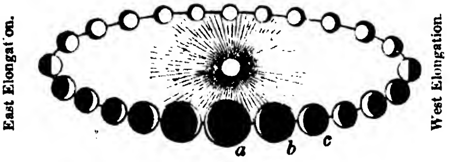
VENUS.

The second planet in order from the sun is the nearest to the earth, and the brightest star in the heavens, shining with a brilliant white light, so resplendently in certain positions as to cause a sensible shadow. Occasionally also, under favourable circumstances, Venus may be caught with the naked eye in the daytime, in the full sunshine. This beautiful orb is at the mean distance of sixty-eight millions of miles from the sun, and accomplishes an orbital revolution in rather more than 224 days, equal to about seven and a half of our months. Having a diameter of 7700 miles, she is but little inferior to the earth in magnitude, and rotates

upon an axis in somewhat less than the terrestrial day. Being farther from the sun than Mercury, the planet is seen at a greater angular distance from the luminary; and is alternately visible for about three hours after sunset and before sunrise, at the time of her greatest elongations, forming the well-known evening and morning star. But occupying an interior position in the system in relation to the earth, Venus, along with Mercury, is never seen at midnight, or in opposition to the sun.

Very definite phases are exhibited by Venus in the course of a periodical revolution — a fine silver crescent and a semicircle—as in the diagram, which represents the various appearances of the planet as she moves round the sun, in the direction of the letters *a*, *b*, *c*. But

Superior Conjunction.



Inferior Conjunction.

PHASES OF VENUS.

Venus can never be seen absolutely full, for when the whole of her enlightened face is towards us, as in her superior conjunction, the solar rays interfere with her splendour. It will be seen from the diagram that the unenlightened half of the orb is turned to us at the

time of the inferior conjunction. If the illuminated side were presented when in that position, we would see the planet as a small brilliant moon shining with twenty times her ordinary lustre, as she is then nearer to us by the whole diameter of her orbit—a hundred and thirty millions of miles—than at the opposite point. West of the sun, or from her inferior to her superior conjunction, Venus is a morning star. East of the sun, or during her progress from the superior to the inferior conjunction, she is the queen of the early night.

The planet is enveloped in a thick atmosphere, in which clouds and vapours are indicated; and we can even see the morning and evening twilight in that distant world, caused by atmospheric reflection. If clouds exist, there must be water also, with the process of evaporation, rain, snow, hail, and electrical phenomena. The twilight of Venus was first discerned by Schroeter; and the subsequent observations of Sir W. Herschel confirmed the interesting fact of its existence. It has been supposed, from certain appearances, that very elevated mountains diversify the surface; but we know nothing positively upon this point.

Under the conditions stated with reference to Mercury, transits of Venus occur, when, deprived of all her radiance, she passes over the solar disk as a spot of inky blackness. Proof is thereby given of the planet being an opaque body; and also that her orbit is included within that of the earth. The transits of Venus are of much greater importance to science than those of Mercury, as, owing to her larger volume and closer neighbourhood to the earth, she is a far more eligible object for the operation of finding the solar distance. But this useful phenomenon is of very rare occurrence.

The first recorded transit was observed in Lancashire under circumstances which deserve detail.

At the time when Liverpool, Manchester, and Leeds, were mere specks of towns, with no commerce but what was carried on by a few barks and pack-horses, there resided in the neighbourhood three remarkable young men—Jeremiah Horrocks, William Crabtree, and William Gascoigne. They were personal friends and correspondents, of similar disposition and kindred pursuits. The two former were the only persons in the world who saw Venus upon the sun's disk, in the year 1639; and no mortal eyes had ever before witnessed the event. The great credit in this observation is due to the first of these individuals, who anticipated the transit, and computed the time. It is to be regretted that few particulars have survived concerning him, for the civil war which brought the reign of Charles I. to a close, broke out soon after the astronomical feat, and buried the very name of the observer in oblivion for a time, and completely arrested the march of science in the land. But the scattered notices that remain of one of our worthies deserve to be collected and garnered, while his achievement is sufficiently memorable of itself to merit commemoration.

Horrocks was born at Toxteth, near Liverpool, in the year 1619—then a paltry hamlet, now an important suburb of a great municipality. His parents were respectable, but do not appear to have been in affluent circumstances. Having given the boy the rudiments of instruction in his native place, they sent him to Emmanuel College, Cambridge, to complete his education; and most likely he trudged no inconsiderable part of the way thither on foot, with books and wardrobe upon his back. He was little more than fourteen

years of age when astronomical pursuits attracted his attention, to which he addressed himself with all the ardour of youthful enthusiasm; and with a genius which would have secured for him a most brilliant career, had his life been prolonged. "I felt great delight," he remarks in a posthumous fragment, "in meditating upon the fame of the great masters of science, such as Tycho Brahe and Kepler; and sought at least to emulate them in my aspirations. I imagined that nothing could be nobler than to contemplate the manifold wisdom of my Creator amid so great a profusion of works, and to behold the pleasing variety of the celestial motions, the eclipses of the sun and moon, and other phenomena of the same kind, no longer with the unmeaning gaze of vulgar admiration, but with a desire to *know their causes*, and to feed upon their beauty by a closer inspection of their mechanism." But serious difficulties lay in the way of these aspirings being realized. His means were limited; the times were not favourable to the tranquil prosecution of philosophical studies, for the public mind was agitated by political storms, the heralds of the approaching bloody contest between the crown and the parliament; and in those days no branch of mathematical or physical science was taught at Cambridge. In spite of these obstacles, Horrocks persevered, with the help of such books as he could procure, and a few associates who had knowledge of astronomical science. Being designed for the church, he finally settled at Hoole, a village to the north of Liverpool, where he subsisted upon a small pittance as a hard-working curate.

When in his eighteenth year, Horrocks had the advantage of becoming acquainted with Crabtree, a young man of scientific attainments, who resided at

Broughton, near Manchester. They soon became intimate, aided each other in their pursuits, and frequently corresponded for the purpose. It is from letters addressed to the physical inquirer near Manchester that we have the chief information respecting his friend near Liverpool. They were together on the evening of the 19th of March 1637, and witnessed an occultation of the Pleiades by the moon. The third of the trio, Gascoigne, was the son of Henry Gascoigne, Esq., of Middleton in Yorkshire. He was about the same age as Horrocks, and, when only eighteen, was actively engaged in advancing the science of optics and practical astronomy, with more facilities at his command than the other two, owing to different worldly circumstance. He invented the micrometer, an instrument used in the measurement of small angles; and was the first who applied the telescope to the quadrant. All knowledge of his instrument was lost upon his death; but twenty years afterwards the micrometer was re-invented by M. Auzout. The distinguishing event in the life of these individuals may now be briefly detailed.

Upon Kepler completing the Rudolphine tables in 1627, which enabled him to calculate the motions of the inferior planets, he predicted that Venus would pass over the sun's disk on the 6th of December, 1631. He died before the time arrived. The transit was looked for, especially by Gassendi, but it was not observed; and Kepler had distinctly announced that it might not be visible in Europe, as the planet would not be in contact with the sun till towards sunset. It is now well known to have taken place during the night between the 6th and 7th. But Kepler had stated, that after this period Venus would not be seen again upon the solar disk till the year 1761. This was

an error. Horrocks suspected it on going over the tables, and comparing them with others. Having repeated his calculations, with all the carefulness and enthusiasm of a scholar ambitious of being the first to observe a celestial phenomenon, he ascertained the correctness of the suspicion to the full satisfaction of his own mind, and found that Venus might be expected to enter upon the solar disk a little before sunset on the 24th of November, o.s. 1639. It appears that the time of the transit was nigh at hand when this discovery was made. Horrocks therefore immediately communicated with Crabtree ; but in an age when electric telegraphs, railways, and stage-coaches were alike unknown, and letters travelled slowly and uncertainly by common carriers, there was no possibility of giving general publicity to the expected event. Hence astronomers at home and abroad, who, depending upon Kepler, had resigned themselves to the thought of the existing generation of men passing away before a transit occured, were not aware that one was near. Two Lancashire young men were alone in the secret, for no mention is made of Gascoigne, as the acquaintance with him was probably of a later date. They prepared to observe the event in their respective dwellings with the best means at their disposal, while king and parliament, church and state, continued their wranglings.

Probably, as November wore on, the parishioners of Hoole might observe their curate at times more abstracted than usual, or more excited, while not a little busy. Probably, also, if this were the case, they might assign it to the perturbations of the kingdom, the signs of the times, and conceive him intent upon joining the politico-ecclesiastical warfare, occupied with

some overpowering pamphlet, intended to stay the breaches in the state, every day becoming wider and more numerous. Horrocks, though not doubting his own calculations, did not deem it prudent to trust implicitly to them. Accordingly, on the 23rd, the day before the event was really expected, he watched the sun at intervals; but only ordinary appearances were noticed. He must have been intensely anxious respecting the next day, for it might be one of November fog, or of clouds, hiding the face of the orb, and thus leaving him in doubt respecting the truth or error of his computations. The 24th was Sunday; and the curate had the services of the church to conduct—" higher duties," as he remarks, " which might not be neglected for these pastimes." However, at a quarter past three in the afternoon, when the public services for the day were over, he embraced the opportunity for observation. " At this time," says he, " an opening in the clouds, which rendered the sun distinctly visible, seemed as if Divine Providence encouraged my aspirations, when oh! most gratifying spectacle! the object of so many earnest wishes, I perceived a new spot of unusual magnitude, and of a perfectly round form, that had just wholly entered upon the left limb of the sun, so that the margins of the sun and spot coincided with each other, forming the angle of contact." Owing to the near approach of sunset, the time of observation was limited to about half an hour; and the sun went down with Venus on his face.

Meanwhile, in the neighbourhood of Manchester, the day opened inauspiciously, and continued gloomy to a late hour of the afternoon. Crabtree had abandoned all hope of being able to test the prediction of his friend, till, just before going down below the horizon,

the sun broke the clouds. Repairing to the room where he had made his preparations, he saw the round black spot with unspeakable delight; and, according to Horrocks, he was so struck with admiration at the spectacle, as to continue gazing upon it, without attempting to take measurements, till it became impossible to do so, owing to the clouds returning. Both observers received the sun's image through a telescope, in a dark room, upon a piece of white paper.

The two friends, humble and obscure, whose names are not even now known to common fame, thus saw what no mortal eye had seen before—an event which one of them had predicted—on the day and at the very hour stated, and which no one was destined to see again till upwards of a century had rolled away. The transit of Venus in the reign of Charles I. was not followed by another till that of George III. had commenced. But more than this. No persons have ever since seen the phenomenon under the same physical circumstances as in 1639. That transit occurred when Venus was passing through the *ascending* node of her orbit. At the two subsequent transits, in the last century, she was at the opposite, or *descending* node; and we must reckon two hundred and thirty-five years from 1639 before there will be a transit at the former node. This carries us on to the year 1874, the time when the planet will next appear traversing the sun's surface at that node. The nodes of a planet are the two opposite points where the plane of its orbit cuts that of the orbit of the earth, or the ecliptic, one half being above it, and the other half below. The point where the planet appears to rise above the orbit of the earth is called the ascending node; and the opposite point, where it seems to go below it, the descending node.

This display of profound sagacity and mathematical acquirement in a youth—for at the time Horrocks was but twenty years of age—cannot fail to excite admiration, especially considering his few advantages. It amply justifies the remark, that had he attained the full age of man, his name probably would have become a household word with future generations in England and the world. Fragmentary papers left behind him contain a beautiful improvement in the lunar theory, which won the praise of Newton, and show him to have had a distinct perception of the perturbative influence which the various bodies in the system exercise upon each other, an idea that had never before been suggested. But in little more than twelve months after the transit his career was suddenly closed by death, under circumstances which have not been particularly detailed.

In October 1640, Horrocks announced to Crabtree by letter, that he intended to undertake a series of observations on the tides, in order, by experiment, to arrive at some definite conclusions respecting their nature. He likewise stated his intention to pay him a visit, but wished beforehand to bring to a close his dissertation on the transit, *Venus in Sole visa*, which must have been then far advanced, as he lived to complete it. In another letter, on the 12th of December following, he noticed the progress of his tidal investigations, and expressed regret at not having been able to pay his visit, alleging as a reason the inconstant state of his affairs, and the harassing nature of his duties. But in a third letter, December the 19th, he wrote to say, that if nothing unusual should occur to prevent him, he would be at Broughton on the 4th of January of the new year—1641. Alas! something

unusual did occur, for on the 3rd of that month he died, in his twenty-third year. On the back of this letter Crabtree wrote a statement to the effect that his dear friend Horrocks died very suddenly on the morning of that day, being the very day previous to that of his promised and expected visit. It appears that Crabtree had been spending some time with Gascoigne in Yorkshire, and that the chief object of Horrocks in his contemplated journey was to obtain information from him respecting the mechanical improvements he had inspected. How much he was admired and beloved, is shown in a letter from Crabtree to Gascoigne, twelve months after the fatal event, in which he ranks him with Kepler, and speaks of him as one "for whose immature death there is scarce a day which I pass without some pang of sorrow." Gascoigne did not long survive. The civil war broke out, and he fell fighting in the ranks of the royalists, at the battle of Marston Moor, in 1644, in the twenty-fourth year of his age. Crabtree likewise died young, in 1652, but no particulars of his decease are known.

Upon the kingdom recovering from the confusion of the civil war, the manuscript of Horrocks's treatise on the transit came into the hands of some members of the newly-founded Royal Society; and the name of the author was rescued from the oblivion into which it had sunk. Huyghens, when in London, read it with delight, and was so struck with its beauty, that he caused a copy to be taken. This was handed to Hevelius, at Dantzic, who published it in 1662; and thus the work of the Lancashire curate was given to the world on the shores of the Baltic. Strange to say, it has never been published in England, nor anywhere else, since the time referred to, and a copy is now

exceedingly rare. The merits of the writer having become known, diligent search was made for other memorials of him. It was found that many of his papers, secreted in his father's house during the wars, had been burned by a party of soldiers, who entered the dwelling for the purpose of plunder. Others, taken to Ireland by a brother, who died there, were irrecoverably lost; and a portion, deposited with a bookseller in London, perished in the great fire of 1666. Some fragments, with the letters to Crabtree, were recovered, and published under the auspices of the Royal Society, in 1672. The dissertation on the transit was not included, because its publication as a separate work was then contemplated. We know not to what extent the name and merits of Horrocks may now be known at Hoole, the place where he observed, wrote, and died; but if no monument exists there to his memory, one might properly be erected for that purpose, as well as in honour of the first observed passage of Venus across the sun.

The transits of the planet excite great interest, owing to their rarity and physical importance. They occur at intervals of eight years—a very small section of individual life—but alternating with intervals of more than a century, during which whole generations pass away, thrones crumble, and dynasties change. They are of importance as the very best means of ascertaining the distance of the sun, and from that element the absolute dimensions of the solar system. The transit of 1761 was well seen; but the discordance of the results obtained at different stations shook faith in the accuracy of the observations. For that of 1769, eight years later, most of the European governments sent out costly expeditions to various parts of the globe,

with the best instruments that could be procured. It was observed by Dr. Maskelyne at Greenwich, Captain Cook at Tahiti, De Fleurieu at St. Domingo, Dymond and Wales at Hudson's Bay. The next transit, as before remarked, will occur December the 9th, 1874; and though not visible in England, it will be watched elsewhere with an eager interest, and with much better instruments than have ever been used before. Another will follow after an interval of eight years, December the 6th, 1882, which will be seen in England, but under unfavourable circumstances, commencing near sunset. There will not then be a transit through the whole of the next century, or till June the 8th, 2004, when another will occur, commencing a little before nine o'clock in the morning. What changes will have taken place during the interval in the history of the world! Long ere then will the destiny of the youngest reader of the present day have been fixed in an eternal state of being.

Owing to her uncommon splendour, Venus has strongly attracted the regard of mankind in all ages. As an evening star, she was known to the Greeks and Romans under the name of Hesperus; and as a morning star, under that of Phosphorus. Hence the invocation of the poet, *Phosphore, redde diem*, "O Phosphorus, restore the day." Twice in the Apocalypse the same expression is metaphorically used to indicate the Saviour of the world:—"And I will give him the morning star," φωσφόρος, the *light-bringer*. "I Jesus have sent mine angel to testify unto you these things in the churches: I am the Root and the Offspring of David, and the bright and morning Star." In a similar manner, that fulness of mental illumination and moral excellence awaiting the church is represented by the

apostle Peter, by the day dawning, and the day-star rising. Grateful to the mariner off an iron-bound coast, and to the traveller in dangerous wilds, after a dark and stormy night, is the star of morn, followed by the cheering and guiding light of perfect day. But though the returning radiance is auspicious, it does not guarantee security. The mariner may suffer shipwreck, and the traveller may perish from the perils of the road, with a bright sky overhead, and the splendid sunshine around them, while under no circumstances does the natural day of itself bring peace to the mind of man. But the "morning star" of holy writ, elsewhere described as the "day-spring from on high," can never be sincerely hailed without the light afforded bringing refreshment and safety to the soul, which neither the changes of time, nor the approaches of eternity, can impair. Hence, while welcoming the sensible day-dawn, it is not more a duty than an inestimable privilege, to rejoice in the beams of the "Sun of righteousness"—"the light of the knowledge of the glory of God in the face of Jesus Christ"—which reveals to us the way of pardon, peace, and immortal blessedness, guides our feet into paths of pleasantness and safety in the present life, and leads the soul to the eternal daylight of heaven in the life to come.

CHAPTER V.

OUR HOME—THE EARTH.

Difficulty of Observation Form of the Earth Proofs of Sphericity – An Oblate Spheroid – Equatorial and Polar Diameter – Area, Bulk, and Density – Rotation upon an Axis – Proof – Cause of the Spheroidal Form – Sidereal Day – Solar Day – Grand Mechanical Expedient – Annual Revolution – Aberration of Light – Solar Year – Reform of the Calendar – Precession of the Equinoxes Its Rate, Cause, and Effects Eccentricity of the Earth's Orbit – Position of its Axis – Succession of Seasons – Superficial Physical Characteristics Division into Land and Water Habitable parts of the Earth – Mountains and Hills The Ocean – Its Saline Constitution – Its Stability – The Atmosphere – Its Extent and Composition – Reflection of Light – Twilight – Refraction of Light Regularity and Grandeur of Operation.

The third member of the planetary system in order from the sun—our own world—has only in very modern times been admitted to its due rank as a celestial body, for the intimate connexion of mankind with their terrestrial habitation, so apparently auxiliary to knowledge, has been an actual obstacle in the way of acquiring correct views respecting it. If we suppose the inmates of a dwelling of comparatively enormous magnitude never to have stepped across its threshold, or to have held intercourse with any who have seen it from an exterior position, it is obvious that they will labour under great difficulties in rightly conceiving of it as a whole, though they may be well acquainted with the outline and aspect of objects within the range of vision from its windows. In a precisely similar manner, yet very feebly expressed by the illustration, confinement to the surface of the earth, and to a very limited horizon at any one time, has operated to hinder the

acquisition of accurate knowledge of its form, dimensions, and general character. For ages men gazed upon the lights of the firmament, and admired their brilliance. They recognised the spherical shape of the sun and moon; and were conscious of movements going on upon a great scale in the outer universe. But not the remotest suspicion was entertained that any of these features belonged to their mother earth. Yet nothing is more susceptible of demonstration, than the convexity of its surface, the incessant motion in space of its entire volume, the smallness of its apparent magnitude viewed from a neighbouring orb, and the luminosity of the opaque mass, reflecting the solar light. Could we visit the surface of Venus, the earth would be seen as a very resplendent object in her night, while as an interior planet to Mars, from his surface, with a telescope, we should witness terrestrial phases, and, at long intervals, see this apparently huge world as a small dark spot transiting the solar disk.

Various fanciful opinions were entertained in early times respecting the figure of the earth. The one most common is supported by the first impression made upon the eye, namely, that it is a continued plane stretching out to an indefinite extent, only interrupted by the inequalities of the land. But its spherical form has long been a received truth; and the evidence of this fact appeals so obviously to our senses, as to render a statement of the arguments which substantiate it almost superfluous. Still, for the information of youthful readers, the principal of them may be briefly adduced.

It is common for vessels on the open ocean to telegraph to each other, while only the upper parts of their masts are visible, the hulls being hid from view by the

convexity of the intervening water. Standing on the shore, on a clear day, watching a ship leave the coast in any direction, the body first disappears, then the rigging, and finally the top-masts, while those on board first lose sight of the strand, then of the ordinary buildings, and lastly of the lofty spires of the port they are quitting. Now circumstances would be precisely opposite if the surface were a dead level, for the largest objects, as the body of the vessel and the buildings of the port, would then be visible longer than the smaller, such as the masts and the spires. In a lunar eclipse also, which is occasioned by the moon passing through the earth's shadow, the form of the shadow projected on the lunar disk is invariably found to be such as one globe would cast upon the surface of another. But navigators steering continually in the same direction, east or west, have come round to the point from which they started, thus decisively proving the fact of the earth's rotundity, east and west. Its convexity north and south is demonstrated by the gradual declination and rise of the north and south circumpolar stars as the equator is approached or receded from. It may be objected, that such inequalities of the surface as the Alps, Andes, and Himalaya, are incompatible with a globular figure. But in reality the greatest mountain heights and oceanic depths are reduced to absolute insignificance, and become insensible, in the view of the earth's comparatively stupendous volume.

Though properly described as spherical, the earth is not a perfect sphere, with its diameters of equal length, and all parts of the circumference at the same distance from the centre. Its true form is that known in geometry as an oblate spheroid, or a globe flattened at the poles. This has been determined with great

nicety and wonderful labour by the measurement of arcs and degrees of the meridian in different latitudes. If the earth were an exact sphere, it is obvious that a meridian, or imaginary great curve passing through the poles and intersecting the equator, would be an exact circle; and that a degree of latitude measured on it would be everywhere of equal length. But instead of this being the case, it has been found, that the length of a degree gradually increases as we proceed from the equator towards the poles, indicating very plainly the greater convexity of the equatorial surface and the polar flattening. The distance through the earth is therefore greater at the equator than from pole to pole, the former diameter exceeding the latter by the $\frac{1}{300}$th of its length. The following are the determinations of the most eminent and recent authorities, using round numbers:—

	Miles.
Length of the Equatorial Diameter . .	7,925
„ „ Polar Diameter	7,899
Absolute Difference, or Polar Compression	26

The other members of the system have the same spheroidal shape, the cause of which will be speedily stated. But the departure from perfect sphericity is much more considerable in the instance of the larger planets. The equatorial diameter of Jupiter exceeds the polar by about six thousand miles; and the disproportion is still greater in the case of Saturn.

Thus our Home-Earth, which seems as a boundless plain to the naked eye, is really a huge slightly-flattened globe, smoother than the rind of an orange, for all the asperities it presents may be regarded as insensible in comparison to its own magnitude. The mean

diameter amounts to about 7,912 miles; the equatorial circumference is nearly 25,000 miles; the superficial area embraces 200,000,000 of square miles; and the cubical bulk contains 260,000,000,000 of cubic miles. If the quantity of matter were piled on the surface of England and Wales, it would form a monster column rising to the height of more than four millions of miles, maintaining throughout the dimensions of the base. The mean density of the varied materials of the terrestrial mass is estimated at rather more than 5½ times that of water, equal to that of ironstone. Hence the earth would counterpoise a globe of ironstone of the same dimensions. But more than five globes of equal size, composed of materials of the same specific gravity as water, would be required to counterbalance our planet. The weight of a cubic foot of water being known, and each cubic foot of the earth being heavier in the proportion stated, the entire weight of the globe is readily computed, amounting to more than 6,000,000,000 of tons. Yet this ponderous orb turns round upon its axis once a day, and is incessantly travelling bodily through space with a swiftness to which that of a cannon-ball is insignificant. These movements will now be noticed in succession.

The rotary movement of the earth upon a fixed axis is not susceptible of being proved in the same manner as the rotation of the sun and of the other planets, which is established by observation of spots upon their surfaces. Yet it might be inferred from the analogy of the solar system. It must be accepted as a truth, or the alternative is inevitable—that the entire celestial sphere is itself carried daily around us. The latter supposition, though sustained by the evidence of the senses, is instantly rejected as incredible, when the number, magnitude, and distances of the stars are con-

sidered; and when the apparent motion of the heavens from east to west is so naturally and easily explained by the real rotation of the earth from west to east. The spectacle of a revolving firmament is obviously an illusion, precisely similar to that of an adjacent shore beheld from the deck of a smooth-going vessel, which appears to be moving in a direction opposite to it, while the passenger is unconscious of his own motion. Accompanying the earth in its smooth and noiseless turning, we seem to ourselves to remain stationary; and the stars appear to travel in a course the reverse of that which we are following.

But the doctrine of the earth's rotation does not rest alone on probability, for a mathematical proof of it is afforded by the experiment of a body descending from a great height deviating from the true vertical line. Of two bodies describing at the same time two circumferences at unequal distances from the axis of rotation, that which describes the most distant, and consequently the greater circumference, must move with more rapidity than the other. The summit of a high tower and its base are in these relative circumstances, as well as the top of the shaft of a coal-pit and the bottom.

Let T represent a tower upon the surface of the earth perpendicular to C the centre. Then *c d* will define the arc described by the summit while the base describes the smaller curve *a b*. It is clear that the summit must move faster than the base. Hence

a ball or stone dropped from the summit, partaking of its greater momentum, will not take the direction of the plumb-line, which it would if the earth were at rest, but deviate from it towards the east, the motion of rotation being from west to east. This has been ascertained to be the case by experiments conducted in St. Michael's Tower at Hamburg, and in a coal pit at Schlebusch, in the county of Mark. Sensible evidence is thus afforded of the fact of the earth's rotation.

The cause of the earth's spheroidal form will now be apparent. As the circuit of the globe is the greatest at the equator, those parts of the surface that are situated there are whirled round the most rapidly. Its equatorial positions move at the rate of more than a thousand miles an hour. From thence, the velocity decreases gradually as the latitude increases, because the circles to be described become less, till at the poles there is no rotation at all. It follows that the centrifugal force, or the tendency of bodies to fly off from the axis round which they move, is the most intense where the rotation is most rapid; and this has so modified the shape of the globe, as to produce the equatorial protuberance and polar compression. It is owing to the same cause, that a pendulum of a given length makes fewer vibrations in a given time at the equator than at other latitudes; and that bodies weigh less there than towards the poles. A pendulum making 86,535 vibrations in a day at London will only make 86,400 at the equator; and hence a clock transported from the former to the latter site will lose upwards of two minutes of time daily. This fact was first noticed in the year 1671 by M. Richer, a member of the French Academy, while upon a scientific mission at Cayenne in South America. Now the oscillations of the pendulum are produced by

the force of gravity, or the power which attracts bodies towards the centre of the earth. If, therefore, they are fewer at the equator than towards the poles, it must be because the force of gravity is less; and this arises from the opposing centrifugal force, or tendency to fly off, being greater, consequent on the greater velocity of the rotation. We may conceive the velocity to be increased till the force of gravity would be neutralized and overcome, when fluids and loose substances, being deprived of weight, would be thrown off the equator as water from a mop when it is trundled.

Every twenty-four hours the earth completes a rotation upon its axis. The exact time is twenty-three hours, fifty-six minutes, and four seconds. This is a *sidereal* day, so called, because it is the time that elapses between consecutive returns of any of the fixed stars to the meridian. The period is unvarying and immutable, for the movement of the earth upon its axis is constantly maintained with perfect regularity; and is, in fact, the only example of strictly uniform motion with which nature supplies us. It is performed in relation to the stars, owing to their immense distance, precisely as if the earth stood still in space, and had no orbit to describe. But this is not the case with reference to the sun, a nearer neighbour, for while the earth is turning upon its axis, the sun appears to move in the same direction nearly one degree a day, in consequence of the earth's orbital revolution. Hence rather more than one rotation elapses between two meridian passages of the sun. This interval is called the *civil* or *solar* day, because of its use to regulate the movements of mankind, while in it there is a complete alternation of light and darkness. The solar day is about four minutes longer than the sidereal. But its length is constantly

fluctuating, owing to the varying speed of the earth in its orbit. Yet to suit the ordinary purposes of society, it is conveniently considered to consist invariably of twenty-four hours.

The rotation of the earth is a grandly simple and admirably perfect mechanical expedient to give to all parts of the surface successively the advantage of the solar beams. To it we owe the vicissitude of day and night, with the resulting phenomena of the cheering sunrise, the resplendent noon, the gorgeous sunset, the calm glory of the eventide, the sensible presence of the glittering stars, and the absorption and radiation of heat. The alternation of light and darkness in the diurnal period naturally marks out to man the intervals proper for bodily activity and repose, for wakefulness and sleep; and physiological considerations show, that the experience of such intervals every twenty-four hours corresponds to the wants of the human constitution. Yet the earth might have been rolled upon its axis with such accelerated velocity as to give us day and night in ten hours; or with such diminished speed as to distribute them over forty-eight hours. That this has not been done, but such a velocity of rotation imparted to the globe as to carry it round in twenty-four hours, giving average intervals of light and darkness adapted to the economy of organized creatures, is obviously no undesigned arrangement, but the appointment of Him "who saw that it was good." Regularly has the rotation been maintained, age after age, fulfilling the primeval promise, "while the earth remaineth day and night shall not cease;" and with unfailing precision the velocity has been preserved, for all history proclaims the uniform duration of the natural epochs of light and darkness. The Divine faithfulness in this

respect is appropriately appealed to as a ground for confidence in the immutability of promises and purposes of grace:—"Thus saith the Lord, If ye can break my covenant of the day, and my covenant of the night, and that there should not be day and night in their season; then may also my covenant be broken with David my servant."

While the earth is every moment turning swiftly on its axis, it is at the same time moving with great rapidity through space, prosecuting an orbit round the sun, and thereby causing the luminary apparently to describe an annual orbit in the heavens. This motion, like that of the rotation, does not come under the observation of the eye, as in the case of the other planets, which are constantly seen changing their place, and returning to it again after definite intervals. But while it might be reasonably inferred to belong to the earth, from the analogy of the system, and is incomparably more probable than to imagine the annual course of the sun to be real, the fact of our translation in space is sensibly demonstrated by the *aberration of light*. The phenomenon thus denoted was discovered by Dr. Bradley in the year 1727. It consists of an apparent displacement of all the fixed stars, by which they seem to describe minute ellipses, accomplished in a year for every individual. To discover its physical cause was an object of intense interest to Bradley, but for a long time he was completely baffled. It could not be explained by means of parallax, or the earth's motion simply, because the observed displacement was in a direction opposite to that which would have been caused by it. At length the solution of the problem was unexpectedly detected. The astronomer was sailing on the Thames with a pleasure-party, in a boat

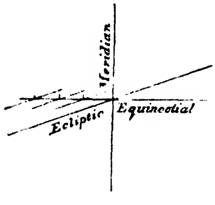
which had a vane at the top of the mast. The wind blew moderately, and the party went several times up and down the river. It was observed by Bradley that every time the boat tacked, the vane at the mast-head shifted a little, as though a slight change in the direction of the wind had taken place. He expressed surprise that every time the boat put about the wind should shift so regularly, but was told by the sailors, that the wind had not shifted, and that the apparent change was occasioned by the change in the direction of the boat. This was the clue that led Bradley to discover the cause of the observed aberration of the stars. Here was an illusion occasioned by the combined motion of the wind and the boat; and on reflection, the happy idea occurred to his mind, that the phenomenon might be accounted for by the progressive motion of light emanating from a star, combined with the motion of the earth in its orbit. It is satisfactorily explained in this way; is completely inexplicable upon any other hypothesis; and establishes the fact of the earth's locomotion by direct and sensible evidence.

Placed in the system at the mean distance of 95,000,000 of miles from the centre, the earth has a path of nearly 600,000,000 of miles to describe in revolving round the sun, and noiselessly pursues the journey at the mean rate of 68,000 miles an hour. A period of 365 days, 5 hours, 48 minutes, and 50 seconds, defines the *solar*, *equinoctial*, or *tropical* year, so called, as it is the interval which the sun appears to take in passing from one equinox, or tropic, to the same again. The ancients measured its length by the gnomon, a vertical pole erected on level ground, whose sharp vertex cast a well-defined shadow. The time when the shadow was the shortest indicated the day

of the summer solstice; and the number of days that elapsed until the shadow returned to the same limit gave the length of the year, which was reckoned to contain simply 365 days.

The civil year was thus made shorter than the solar. To bring the two into coincidence, the Roman calendar, as reformed by Julius Cæsar, added a day to every fourth year, making it to consist of 366 days. But this involved an error in excess, amounting annually to eleven minutes, which, though trifling, speedily accumulated to an error of hours, and, in the lapse of centuries, to one of days. It had, in fact, amounted to an error of ten days by the year 1582, when, to remedy the inconvenience, pope Gregory the XIIIth published a bull, cutting off ten days from that year, by directing the 5th of October to be reckoned as the 15th, and adopted other regulations to prevent the return of similar confusion. The Gregorian, or new style, was not established in Great Britain till the year 1752, by which time the error of the old reckoning had been increased by an additional day. Hence, by Act of Parliament, eleven days were suppressed in the year referred to, by the 3rd of September being called the 14th. This enlightened measure, which merely corresponded civil to natural time, raised a violent outcry among the ignorant classes, as if it actually defrauded them of the due number of their days, and profanely intermeddled with the prerogative of Providence in appointing the times and the seasons. "Give us back the eleven days we have been robbed of," was the cry of the mob at a contested election for Oxfordshire; and the subsequent death of Bradley, the Astronomer Royal, was popularly regarded as a judgment upon him for his share in the transaction.

The solar, or tropical year, is not the exact period of the revolution of the earth in its orbit, owing to the *precession of the equinoxes:*—a movement somewhat difficult to render popularly intelligible. The equinoxes, vernal and autumnal, are those points where the sun, in the apparent annual circuit of the heavens, crosses the equinoctial, or the plane of the terrestrial equator extended to the celestial concave. They are so called, because the days and nights are then of equal length all over the globe. But these points are subject to a slow constant displacement; and are every year a little to the west of those of the year preceding. Let the horizontal line represent the equinoctial; the



oblique line the ecliptic, or the sun's apparent path; and the vertical line the prime meridian, or first point of Aries, from which celestial longitude is reckoned. Now the sun, moving in the ecliptic, after making one complete circuit, does not return again to cross the equinoctial at precisely the same point as before, but at another a little behind, or to the west of it. This is repeated every year; and is illustrated in a homely manner by the short lines in the diagram. Hence the return of the sun to the same equinoctial point *precedes* its return to the same point in the ecliptic. As the rate of precession amounts to fifty seconds annually, this arc has to be described, requiring about twenty minutes, in order to a complete revolution of the sun in the heavens, or—which is the same thing—of the earth in its orbit. The period of revolution consists, therefore, of 365 days, 6 hours,

9 minutes, and 10 seconds. This is called a *sidereal*, or *astronomical* year, because it is the time occupied by the earth in its orbit, or the sun in the ecliptic, in moving from a determinate point in relation to any fixed star to the same point again.

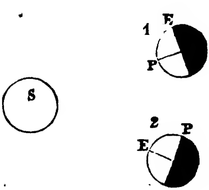
The precession of the equinoxes, apparently a change in the point of the sun's passage across the equinoctial, is really a change in the point of the earth's orbit at which its two hemispheres are equally exposed to the sun. Hipparchus, the Greek astronomer, first detected this movement, by observing a progressive increase in the longitude of the stars. Its cause remained unknown till Newton showed it to be a necessary consequence of the earth's spheroidal form, and the unequal attraction of the sun and moon on its equatorial and polar regions. As there is more matter about the terrestrial equator than about the poles, the former is more strongly attracted than the latter, which causes a slight reeling motion from east to west of the axis of the earth around the poles of the ecliptic, and the shifting westward of the equinoctial points. This motion, being at the rate of $50''$ annually, amounts to $1°$ in rather more than 71 years, and to $30°$, an entire sign, in 2,160 years. Consequently, in the cycle of 25,920 years, the equinoxes will move through the whole of the twelve signs of the ecliptic, make a complete circuit of the heavens, and return to the same position among the stars. It follows that the longitude of the stars, being counted from the first point of Aries, is continually increasing. It has increased upwards of $30°$ since the first catalogues were made; and hence, instead of the signs of the ecliptic at present corresponding to the constellations after which they are called, they lie more than $30°$ to the westward of them.

Undoubtedly, in the infancy of astronomy, when the ecliptic was first divided, and the divisions, or signs, were named, the several constellations lay in those they denominate. But now, owing to the precession of the equinoxes, the constellation Pisces is in the sign Aries, the constellation Aries is in the sign Taurus, and the tropics of Cancer and Capricorn, according to the sun's place among the stars, have become the tropics of Gemini and Sagittarius.

In its annual revolution, the earth describes an ellipse of slight eccentricity. Still the form of the orbit so far deviates from the circle, that we are nearer the sun by about three millions of miles towards the close of December, than at the opposite season, the end of June; and a corresponding variation is perceptible in the apparent diameter of the solar globe. It takes the uninformed by surprise to learn, that during the height of our summer, the earth is in that part of its path which is most distant from the sun, while during the severity of our winter it approaches the nearest to it. But the difference of the earth's distance from the sun in summer and winter is but inconsiderable, when compared with its total distance; and whatever change of temperature might arise from it under other conditions, is completely overpowered by the causes which produce the variations of the seasons. In winter, the solar rays reach us most obliquely, as the sun then rises to its least altitude above the horizon; and in proportion to the obliquity of the direction is a less number received on any given surface. It is also the case, that both light and heat are absorbed in passing through the atmosphere; and a ray will obviously have to traverse a larger extent of the atmosphere, according as the direction deviates from the perpen-

dicular. Hence, as the sun of morning and evening is at all times less influential than that of the mid-day, so is the sun of winter less potent than that of summer. But the principal cause which overpowers the effect of variation of distance is, that in winter, when the earth is nearest the sun, the days in which heat is received are much shorter than the nights, when heat is lost. On the other hand, in summer, the effect of the increased distance of the sun is much more than counterbalanced by the increased length of the days and shortness of the nights.

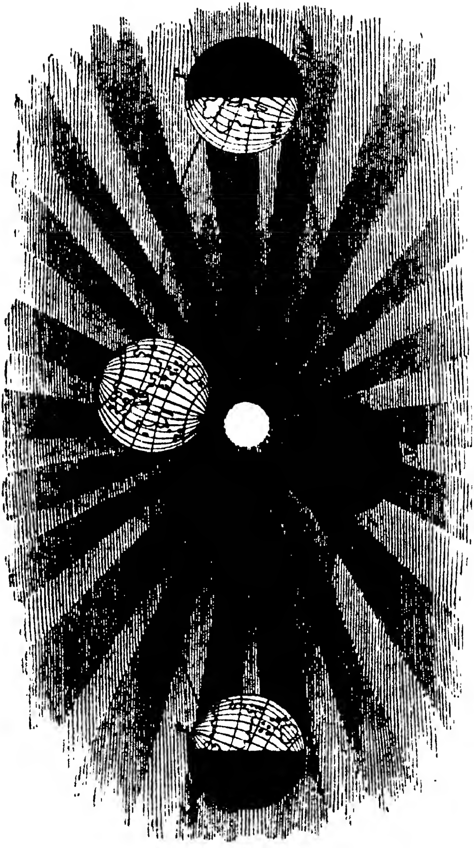
The motions of our globe which have now been noticed, the diurnal rotation and annual revolution, with the direction and unvarying position of its axis, originate that pleasing variety of seasons which we experience, spring, summer, autumn, and winter, with their changes of temperature, different products, and diversified natural scenery. No physical law requires the rotation of the earth to be conducted as it is, either with reference to the velocity of the movement, or the direction of the axis. But while, as before remarked, the rate is adjusted to the welfare of organized creatures, so is the position of the axis of rotation. If one of the poles had been pointed to the sun (fig. 1), we should then have had one half the earth constantly in the light, and the other half in perpetual darkness, notwithstanding the motion of rotation and revolution. Or if the earth had its equator always in that position (fig. 2), then, by the daily rotation, all places would be alternately in light and dark-



ness for equal portions of time throughout the year: and though there would be different seasons in different parts of the earth, there would be no change of seasons at every place, as at present. But both these consequences are avoided by the axis of the earth being inclined 23½° from a line perpendicular to its orbit, which is constantly retained during its annual circuit. By means of this simple arrangement, the northern and southern hemispheres lean *to* and *from* the sun, and days and nights of unequal length are experienced, the main cause of that diversity of seasons, which is so refreshing by contrast, convenient to mark the course of time, and subservient to the general well-being of plants, animals, and man.

A glance at the annexed sketch will show how the obliquity and constant parallelism of the earth's axis cause the several portions of the surface to receive varying amounts of the solar influence in different parts of the terrestrial orbit. At the vernal and autumnal equinoxes, in March and September, the sun shines equally upon the earth from pole to pole; and the daily rotation distributes equal portions of light and darkness over the globe. But at the summer solstice, in June, the northern hemisphere, being most inclined *towards* the sun, has its longest days and shortest nights; while at the winter solstice, in December, being most inclined *from* the sun, it has its shortest days and longest nights. The same effects follow from the same cause in the southern hemisphere, but at a different period; for as we pass from summer to winter, the inhabitants of southern zones are passing from winter to summer.

Among the physical characteristics of our planet, superficially considered, the most prominent and



distinguishing is its division into land and water. These components of the surface occur in very unequal proportions, and are most irregularly distributed. According to usual estimates, the waters have the dominion over two-thirds of the globe, and of the remaining third, or the dry land, by far the largest amount is found in the northern hemisphere. We can assign no reason for this unequal proportion and irregular distribution, but contentedly fall back upon the sacred record: " And God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear: and it was so. And God called the dry land Earth; and the gathering together of the waters called he Seas: and God saw that it was good." While the habitable parts of the earth are chiefly in the northern hemisphere, they are also to the greatest extent in the temperate zone—an arrangement of the first importance, as being favourable to the development of energetic populations. The Esquimaux, Laplander, and Samoiede, represent man as an arctic dweller; the Negro, Hindoo, and Polynesian, as a tropical inhabitant: and, as far as history throws its light upon the past condition of the human race, all these families have been as they now are, far inferior in intellectual vigour and social improvement, to the nations subject to the climatic influences of the broad intermediate zone, the Greek, Roman, Frank, and Anglo-Saxon.

As the dry land is distinguished from the waters of the ocean by elevation, so its most remarkable external features are the immediate results of upheaving forces, exhibited in the phenomena of mountains and hills. These inequalities are endlessly varied in their aspect and outline, and render the landscapes of nature highly impressive, picturesque, or beautiful, by their diversity.

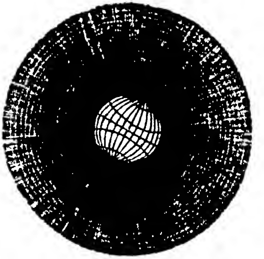
They both appear as isolated masses in the midst of extensive plains, and are arranged in groups of irregular form, or in chains of tortuous course. They rise in gentle round-topped downs, upon which the sheep-bell tinkles and the daisy blows; and are developed in colossal piles, where the chamois and the rock-goat, the eagle and the condor, have their haunts and homes. Some are carpeted with grass, or clothed with woods; others present the naked granite to the eye, here and there patched with moss and lichens, while fantastically worn along the slopes by the rush of cascades, and the action of rains. The clouds float far below the crests of the loftier elevations, and the grand heights have their summits crowned with masses of ice, and mantled with perpetual snow. These superficial irregularities fulfil important functions in the economy of nature. The vapours in the atmosphere, drifted by the winds, are arrested by the hills and mountains; and being condensed by contact with their cold summits, they precipitate themselves in the abundant showers common to such districts. In tropical countries, where the summers are dry and hot, the plains at the base of grand highlands are well watered, long after the season of drought has commenced, by the melting of the snows accumulated in winter upon the elevations. Supposing the mountains brought low, the valleys filled up, and the surface turned into a dead level, the land would soon cease to be dry and habitable; for as there would be no drainage, the rains would convert the entire solid superficies into a morass, incompatible with the preservation in comfort and life of the higher forms of animated existence. But by the existing diversities, the showers of heaven form the rippling brooks, the latter unite in streams,

which become confluent in rivers; and the rivers run into the sea, after a course of useful irrigation. Well, therefore, might the leader of Israel speak of the "chief things of the ancient mountains," "the precious things of the lasting hills."

The fluid portion of the surface, the sea, next to its vast extent and tidal phenomena, noticed in a subsequent chapter, is chiefly remarkable for its saline constitution. Though this quality is not uniform, it is universal; for whether dashing against the icebergs of the poles, or warming beneath the sun of the equator, the ocean is eminently the salt sea. No satisfactory natural explanation can be given of this peculiarity. It completely baffles scientific investigation; for if we suppose the saline constituents to be derived from immense beds of fossil or rock-salt at the bottom, or to be carried down by springs and rivers from the land, the ocean ought to be gradually becoming salter, which is contrary to observation. The only solution of the problem put into our hands—quite sufficient—is, that "the sea is His, and he made it." It is now, as it has been from the beginning, and will be through future time, in this saline condition, just as the atmosphere is not simple, but a compound of gases; and both subjects are equally shrouded in mystery. But utility may be discerned in the arrangement. While mankind obtain a considerable proportion of common salt from sea water, by processes of evaporation, the saline ingredients invest the ocean with superior buoyant powers, and thus facilitate navigation. A larger area of it is also preserved from being ice-bound. Under ordinary circumstances, fresh water freezes at 32° Fahrenheit, whereas sea water requires a degree of cold equal to 28° to be frozen. It is striking to reflect,

that while unstable in relation to itself, and tremulous to the slightest breeze, the ocean is yet a grand example of stability. The "brook decayeth and drieth up;" all streams shrink in times of drought, and are liable at other seasons to become desolating water-floods. But by unalterable laws of evaporization and condensation, the sea is kept at a fixed point, and knows nothing, as a whole, of increase or decrease. "He gave to the sea his decree, that the waters should not pass his commandment."

A gaseous covering, or atmosphere, incloses the entire solid and fluid surface of the earth, travels with it in space, shares its diurnal rotation, with the vapours which float upon it, and is preserved in connexion with it by the attraction of gravitation. Supposing the clouds stable, and the atmosphere perfectly calm, then a cloud suspended over a given part of the earth's surface would be found hovering over precisely the same spot twenty-four hours afterwards, having made a complete rotation with the spot round the common axis. In consequence of this motion, the



aerial envelope must form an ellipsoid, dilated at the equator, and flattened at the poles. Its mean height is estimated at from forty-four to forty-seven miles; its volume as the twenty-ninth of that of the globe; and its weight only forty-three thousandths. But the greater portion of the atmosphere is comparatively near the

surface, as its density so rapidly diminishes upwards, that at heights attainable by man it is attenuated to such a degree as to inconvenience the respiratory organs. The " difficult air on the iced mountain's top" is well known to the climbers of high mountains. The appendage consists essentially of dry air, composed of two gases in definite proportions; and while all organic life depends absolutely upon its chemical constitution, its mechanical agency, as indicated by winds and temperature, is not less essential to the preservation of the animal, vegetable, and human races. Clouds and vapours are suspended in this stratum, and form parts of the practical, but not of the true atmosphere. They bear the same relation to it as the earthy particles of a turbid river bear to the fluid in which they float. Without an atmosphere, it is certain that the earth could not be occupied by its present inhabitants. It is expressly fitted and designed for them; and they are as plainly constituted for it. The existence of such an apparatus in connexion with any globe may therefore be accepted as evidence, by itself, of adaptation for organized existences; and in the case of Venus, Mars, Jupiter, and Saturn, unequivocal indications of atmospheres are afforded.

While necessary to life in all its important forms, and ministering in a thousand ways to the convenience and pleasure of man, the terrestrial atmosphere claims the attention of the astronomer, chiefly in relation to its action upon the rays of light which traverse it. Having to pass through this medium, the intensity of sunlight is mitigated by it, just as the glare of a gaslight is moderated by a globe of ground-glass around it. The solar illumination is also agreeably diffused in every direction by the particles of air

possessing the property of successively reflecting and re-reflecting it. Without this scattering property, no object would be illuminated, indirectly situated with reference to the luminary. We should know no other alternation than between the fiercest glare and the profoundest shade; the stars would be as visible by day as in the night; and, with the exception of the places occupied by them and the sun, the cloudless noontide firmament, now so bright and blue, would present to us the blackness of darkness. Morning and evening, we pass from night to day, and from day to night, not abruptly, but by an easy transition, because, while the sun is below the horizon within certain limits, his rays directly illuminate the upper regions of the atmosphere, and they are thence transmitted to us by reflection. Hence we have the dawn brightening into day, and the evening twilight deepening into night. This effect is produced in our latitude while the sun is within 18° of the horizon. But practically, as regards the duration of twilight, much depends upon the atmosphere being free from mists and clouds, or surcharged with them.

The atmosphere, not being a medium of uniform density, may be considered to consist of different media, which increase in density as they approach the surface of the earth. Hence, in traversing them, the rays of light are more and more refracted, or bent out of a straight course, while passing to the eye of an observer; and as the increase of density takes place by insensible degrees, they take a curved direction, the concavity of which is turned towards the earth's surface. It will easily be understood, that owing to this refraction, all the heavenly bodies, except in the zenith, must appear above their real position, since we always

refer objects to a place in the straight line of the direction of the ray, at the moment it enters the eye. It follows, that sun, moon, and stars, are seen for a short time before they actually rise, and for a short time after they have set.

In giving the earth to the children of men, the Most High prepared it for their accommodation with wisdom, benignity, and power; for while the arrangements of terrestrial nature abound with instances of skilful and beneficent contrivance, their efficiency has been maintained unimpaired age after age. "For ever, O Lord, thy word is settled in heaven. Thy faithfulness is unto all generations: thou hast established the earth, and it abideth; they continue this day according to thine ordinances: for all are thy servants." Days, with the succession of light and darkness, the morning and evening twilight, have followed each other at definite intervals with precision, by the earth rolling upon its axis with uniform velocity; years, with the cycle of the same seasons, have revolved with unfailing regularity, because the course of our planet round the sun has been incessantly pursued, never shifting the direction of the axis of rotation; the atmosphere has faithfully performed its functions, the ocean has steadily kept its bounds, and the continents have everywhere had their vegetation spontaneously renewed, while, as the reward of industry, giving seed to the sower, and bread to the eater. Familiarity with the phrases, diurnal rotation and annual revolution, is apt to weaken impressions respecting the movements they denote. But their magnificence, ease, and noiselessness amply deserve attention. It is a truly astonishing thought, that, "awake, asleep, at home, abroad," we are constantly carried round with the terrestrial mass, at the

rate of eleven miles a minute in our latitude, and are, at the same time, travelling with it in space with a velocity of sixty-eight thousand miles an hour. Thus, during the twenty minutes consumed in walking a mile from our thresholds, we are silently conveyed more than twenty thousand miles from one portion of space to another; and during a night of eight hours' rest, or tossing to and fro, we are unconsciously translated through an extent equal to twice the distance of the lunar world. Viewed in connexion with parallel phenomena in the system, such examples of ponderous masses combining marvellous velocities with perfect order, will seal the truth upon the reflecting mind, "The Lord God omnipotent reigneth." "Blessed be the Lord God, the God of Israel, who only doeth wondrous things. And blessed be his glorious name for ever: and let the whole earth be filled with his glory."

CHAPTER VI.

THE LESSER LIGHT.

Scheme of Satellites—Magnitude and Distance of the Moon—Variation of Distance—Proper Motion of the Moon—Sidereal and Synodic Revolution—Phases of the Moon—Lunar Crescent—Earth-light—Months and Weeks—New Moon of the Jews—Rotation upon an Axis—Its Peculiarity—No Atmospheric Indications—Dusky Patches on the Disk—Singular Explanation—Lunar Maps—Models—Supposed Lunar Seas—Evidence of Superficial Inequalities—Mountains of the Moon—Remarkable Structure—Ring-mountains and Bulwark-plains—Tycho—The Apennines—Eratosthenes—*Mare Imbrium* described—Supposed Lunar Effects—Influence on the Weather—Felling Timber—The Red Moon—Statements of Travellers—Explanation—Lunacy—The Tides—The Harvest Moon—General Inference.

THOUGH one of the most inconsiderable bodies in the heavens as to magnitude, the moon is to mankind, next to the sun, the most engaging and useful, as the light that "rules the night," the main cause of the tides, while guiding the mariner across the ocean by the advantage which science has taken of her rapid changes of position with reference to the stars. In courtly and rustic life—in palaces and cottages—the lunar world has been regarded in all ages with respect and admiration, as an emblem of modest beauty and faithful attendance; and while her varying aspects have indicated to barbarous tribes weeks and months, times and seasons, astronomers have studied them with greater attention than any other celestial appearances, owing to her greater proximity bringing the orb within more convenient range of their telescopes. Some of the finest bursts of poetry have been inspired by the

placid loveliness of the queen of night, such as the description of the Greek bivouac in the Iliad, the merit of which, in the following version, is perhaps less due to Homer than to Pope:—

> " As when the moon, refulgent lamp of night,
> O'er heaven's clear azure spreads her sacred light,
> When not a breath disturbs the deep serene,
> And not a cloud o'ercasts the solemn scene;
> Around her throne the vivid planets roll,
> And stars unnumber'd gild the glowing pole;
> O'er the dark trees a yellower verdure shed,
> And tip with silver every mountain's head;
> Then shine the vales, the rocks in prospect rise,
> A flood of glory bursts from all the skies:
> The conscious swains, rejoicing in the sight,
> Eye the blue vault, and bless the useful light."

With this stedfast companion of the earth the scheme of satellites in the system commences; and, with the exception of Mars, it is a feature belonging to the great planets exterior to the earth. The want of a satellite, in the instance mentioned, may be provided for by the extent and density of the planet's atmosphere. These secondary bodies are not improbably designed to supply their primaries with reflected solar light when deprived of its direct beams, and to compensate for the diminished power of the " sun's directer ray," consequent on their vast distance. Hence, while the earth has only a single moon, Jupiter, at five times its distance from the luminary, has four; and Saturn, at nine times the distance, has eight, with an apparatus of rings, equal in illumination to many such attendants. The still more remote planets are similarly provided, and may have extensive trains which escape our notice, owing to the immensity of the intermediate space. Of the twenty satellites at present recognised as belonging to the system, nineteen would have remained for ever unknown but for the telescope. Of these, nine have been discovered exclu-

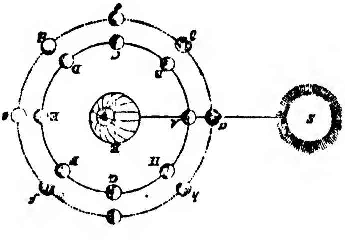
sively with the refracting, and nine exclusively with the reflecting telescope, while the remaining one was discovered by the independent, but simultaneous use of two instruments, a refractor and reflector. It is probably a law with all these secondary bodies, that they have an axial rotation, performed in exactly the same time as their revolution round their primaries. This is true of our own moon, and of the satellites of Jupiter; but it is one of those mechanical arrangements in the universe utterly inscrutable in its design.

The moon, though apparently as large as the sun, is the smallest of all the heavenly bodies obvious to the naked eye, having a diameter of only 2153 miles. Her surface is, consequently, thirteen times less than that of the earth; her bulk forty-nine times less; and it would require seventy millions of such bodies to be rolled together to equal the volume of the sun. But the mean distance of the moon from the earth being but 237,000 miles, or one four-hundredth part that of the sun, she rivals the great orb of day in apparent magnitude, and figures conspicuously in the nightly firmament. Moving round the earth in an elliptical orbit, the real distance of the satellite varies to the extent of 30,000 miles; and the apparent lunar diameter varies proportionably, from 33′ 31′ when nearest to us, to 29′ 21′ when furthest off. This variation of distance and apparent diameter is made manifest by eclipses. Sometimes, as when nearest the earth, the lunar disk is larger than the solar, and a total eclipse of the sun is caused by its interposition. At other times, when most distant, the lunar disk is smaller than the solar, and under similar circumstances, a portion of the sun is seen encircling the dark orb of the moon, producing a ring-like, or annular eclipse.

In the infancy of the human race, the varying aspect of the moon, while a charming novelty, must have seemed a strange mystery. The phenomenon stood alone in nature to them. Heaven and earth presented no analogous appearance. Day after day mankind saw the sun rise, climb the sky, and decline to the horizon, always round and brilliant. Night after night they beheld the stars shine out, with uncrippled splendour, with unaugmented brightness. But the moon was ever varying her phase, ever waxing and waning; sometimes invisible, now a silver crescent, hanging in the western sky, and anon full-orbed, dimming the stars with her radiance. At first, the ancients had no conception of any motion in the heavens apart from the apparent diurnal revolution of the sphere from east to west. But the moon's proper motion inverse to it, or from west to east, must speedily have forced itself upon their attention; and though the fact is not on record, it may be confidently regarded as the first astronomical discovery ever made by human observation. Rapidly the satellite shifts her position in relation to the stars. If viewed in the neighbourhood of any particular star on a clear night, she will have passed to the eastward of the star on the following night by about 13°; and so on every night, till she is seen approaching to the same contiguity to the star from the westward, having made the entire circuit of the heavens, and completed a revolution round the earth. The lunar journey is accomplished in 27 days, 7 hours, and 43 minutes. This is the moon's periodic time, called a *sidereal* month, because she returns in the interval to the same place among the stars. But as, while performing this revolution, the earth is advancing in its orbit in the same direction, upwards of two days more are required for

the moon to exhibit the same phase, by getting into the same position again with respect to the earth and the sun. Hence a *synodic* period, or lunar month—the interval between one phase and the same again—is longer than one complete orbital course, consisting of 29 days, 12 hours, and 44 minutes.

During this monthly pilgrimage, the illuminated lunar hemisphere successively assumes different positions in relation to the earth; and hence changes of aspect are periodically exhibited. These beautiful and well-known varieties of appearance prove that the moon is not a self-luminous body, but shines by borrowed light, reflecting a portion of that received from the sun. If it were not so, the satellite would have one unvarying phase; and, being globular, would always



PHASES OF THE MOON.

appear as a round full orb. Suppose E the earth; S the sun; and A B C D E F G H the moon in eight different parts of her orbit. Then *a b c d e f g h*, in the outer circle, show the phases presented to a terrestrial spectator at each station of the lunar globe. When at A, between the earth and the sun, no portion of the luminous side is seen. The moon is consequently invisible;

and in this position is said to be in *conjunction*, and to *change*. Having advanced to B, a small portion of the enlightened side comes into view, and appears as a thin crescent, as represented at b. The crescent gradually enlarges as the moon proceeds in her orbit, till it is effaced, for at C, half of the illuminated hemisphere being presented to the earth, the moon appears halved, or a semicircle, as at *c*. Arrived at D, considerably more than half the luminous side is seen, and the moon is said to be gibbous, or hump-backed, as at *d*. It is completely disclosed at E, when, being on the opposite side of the earth to the sun, or in *opposition*, the moon appears full, as at *e*. Setting out from this point, the same phases are repeated, but in an inverse order. The two positions of conjunction and opposition are called *syzygies*, a Greek compound, signifying "yoked together," for the sun, earth, and moon are then in a line; and it is in these positions that eclipses occur. The intermediate points are the *quadratures*, the moon's first and last quarters, in each of which she is one quarter of her circuit from the sun; and the points intermediate to these are four of the *octants*, or eighths of the lunar orbit.

The crescent moon, the most interesting of the lunar phases, has always its convexity towards the sun; but its direction changes on changing sides with the luminary, being westward in the instance of the waxing moon, and eastward with reference to the waning orb. It has happened, that, just before sunrise, the finely attenuated crescent has been noticed in the east, the moon then approaching nearly to conjunction; and in the evening of the following day, having passed the change, the opposite crescent has been observed in the west. In the early days of the new moon, under fa-

vourable conditions of the atmosphere, we can see distinctly the obscured portion of the orb, an appearance popularly known as the "old moon in the new moon's arms." This arises from the reflection of the sun's light by the earth, or what may be called earthlight at the moon, as properly as we speak of a similar reflection as moonlight. It is the strongest at the interval referred to, because, when the moon is *new* to us, the earth is *full* to the moon, and is splendidly shining in the lunar sky. A small portion of this earthlight being re-reflected, renders feebly visible those parts of the lunar disk which are not receiving the direct rays of the sun. The returned earthlight is therefore the "reflection of a reflection;" and is called by the French, *la lumière cendrée*, "the ashy light," in allusion to its faintness.

The lunar phases, by their periodical occurrence and uniform aspect, furnish a standard for the division of time into definite periods, and supply mankind with the means of readily marking and computing its progress. While the circuit of the moon round the earth supplies the lunar month, the different aspects of the satellite at the four quarters of her course distribute the lunation into weeks. This was one of the purposes of the Almighty in placing the "lesser light" in the firmament. "He appointed the moon for seasons;" and most convenient to mankind has the arrangement been. Hence the Mosaic law enjoined special religious celebrations upon the Jews at the beginning of their months, as an expression of their dependence upon God, and of their gratitude for the natural blessing. Ignorant of astronomical calculations, ih the early periods of their history, they were guided by actual observation of the moon in the commencement of the

month; and the new moon was not proclaimed till two credible witnesses testified that they had actually seen it. The fact was commonly certified by several independent couples of witnesses, who had stationed themselves on the tops of hills, to watch for the lunar crescent in the western heavens, anxious to be the first bearers of the welcome intelligence. The trumpets of the priests announced the event in the city; signal-fires proclaimed it to the country; and the particular offerings ordained by the law followed. Hence the language of the Psalm: "Blow up the trumpet in the new moon, in the time appointed." But in a degenerate age, the institution was completely perverted from its original design. God was forgotten in it; and while the occasion itself was celebrated, it was with revelling as well as rites, which gave rise to the rebuke: "Your new moons, and your appointed feasts, my soul hateth."

Besides revolving round the earth, the moon turns on an axis; and, by a remarkable law, the time of rotation is exactly equal to the period of revolution. This is not an obvious movement; but it is demonstrated by the fact, that the same side of the moon is always presented to the earth, as is evident from her surface exhibiting constantly the same readily recognised marks in the same positions. We should of course see all round the moon, in accomplishing her monthly circuit, if she did not turn round upon herself, rotate and revolve in equal times. Small portions of the disk, east and west, north and south, are indeed alternately presented and withdrawn, as if the orb slightly oscillated in those directions. These appearances are known as the moon's *librations*, the former being in longitude, and the latter in latitude, and are

caused by the orbital motion being irregular, while that of the rotation is quite uniform. The effect is, alternately to extend and diminish the sides of the exhibited surface, thus allowing us transiently to overlook a little more of the disk on the equatorial and polar edges. But these variations do not at all affect the statement, that the moon always presents the same hemisphere to the earth; and this is at once the consequence and the proof of one rotation upon an axis being performed in the time of one revolution. If we suppose a person to walk in a circle round a tree, keeping his face invariably directed to the trunk, he will, upon completing the circuit, have looked east, west, north, and south, or entirely round the horizon, and must, therefore, have turned round upon himself.

There is great peculiarity in this correspondence of the period of rotation to that of revolution. While one half of the lunar world is, in consequence of it, for ever hid from us, our entire globe is for ever concealed from a whole hemisphere of the moon. A parallel arrangement in relation to the earth would be, for the moon never to appear in the sky of Europe and Africa, and for a European and African to have no personal knowledge of the luminary, except by travelling towards Eastern Asia or Western America. It follows, also, that as the moon rotates upon her axis once a month, she has one alternation of day and night, sunlight and darkness, in the interval, each extending to nearly a fortnight. But strikingly different will be the nights of the opposite lunar hemispheres. The one perpetually turned from us will be unrelieved, except by the illumination of the stars. The other will have earth-light far more intense in its illuminating power than moonlight to ourselves, as the earth will appear in the

lunar sky thirteen times larger than the moon does to us. An inhabitant, if such there be, at the edge of the visible disk, will see the earth at the horizon. By one towards the centre it will be seen near the zenith.

Another peculiarity of the satellite is the absence of an atmosphere, or at least of one at all available for the same purposes as our own. This seems certain from the fact, that while definite indications of such an appendage are afforded in the instance of several of the planets, millions of miles away from us, no traces of it are furnished by the moon, so incomparably nearer, either in eclipses or occultations, or by the presence of clouds varying the brightness of the disk. Hence it follows, that the solar light and heat at her surface will be fierce in the extreme, being untempered by the medium. But owing to the absence of a volume of air, by whose reflective and refractive powers the rays of light are diffused, and the firmament is painted with its delicious blue, every object out of direct sunshine, or lateral reflection, will be involved in darkness, while the sky apart from the sun, earth, and stars, will be pitchy black. Without an atmosphere there can be no rain, hail, or dew, and various other phenomena with which we are familiar, nor is there the least trace of a liquid of any kind at the surface. In proportion as the moon has been examined with powerful telescopes, apparently sharp superficial asperities have been rendered sharper, and the evidence has become more distinct, that it is not a water-worn world.

Diversity of the lunar surface is obvious to the naked eye, in large, irregular, and variously-shaded patches on the disk, with brighter tracts. These appearances have excited the curiosity of mankind from the earliest and have been imagined to be the outlines of

continents, seas, islands, mountains, and valleys, analogous to those of our own globe. The opinion also prevailed in ancient times that these configurations represent the terrestrial geography reflected back to us by the moon as in a mirror. This idea was held by Agesianax, and contested by Plutarch. However fanciful, it is not unnatural; and hence it has suggested itself to many minds in a wholly independent manner. At the present day in Western Asia it is an article of popular belief. "I was once very much astonished," observes Humboldt, "to hear a very accomplished Persian of Ispahan, who had certainly never read a Greek book, to whom I was showing, in Paris, the spots on the moon's face through a large telescope, propound the same hypothesis of reflection as that of Agesianax, as prevalent in his own country. 'It is ourselves we see in the moon,' said the Persian: 'that is the map of our earth.'" Mr. Crampton mentions, that a friend maintained a long and grave argument with him in support of this theory, without being aware that the idea had ever been entertained before.

Soon after instruments were turned upon the satellite, lunar maps were constructed, giving the result of telescopic observation. Hevelius of Dantzic led the way, publishing his "Selenographia" in 1647, which contains a description of the moon illustrated by charts, drawn and engraved with his own hands. In 1651, Riccioli produced a map of the satellite, which was followed in 1680 by Cassini's chart; and this again, about seventy years later, by that of Tobias Meyer, which remained in general use down to a recent date. The fine work of the Prussian astronomers, M. M. Baer and Mädler, entitled "Der Monde," published in 1837, far surpasses any thing of the kind ever exe-

cuted. It contains a large map of the moon, rather more than *three feet in diameter*, in which its physical aspect is very fully and minutely delineated. Special charts also, representing particular portions of the disk, have from time to time appeared; and attempts have been made more adequately to realize lunar appearances by means of models, constructed to project the inequalities on a spherical surface. Thus the two lunar craters, Eratosthenes and Maurolycus, were represented in plaster of Paris by Mr. Nasmyth. The most remarkable work of this kind is a model in relief of the whole visible hemisphere, composed of mastic and wax, executed by Madame Witte of Hanover, from observations made by herself from the roof of her own house. The moon has likewise been made to take her own likeness; but no result has hitherto been obtained by the photographic process which has advanced knowledge of her physical features. Upon this point very sanguine expectations have been indulged, owing to the increased power of telescopes, such as that objects of no greater magnitude than an ordinary terrestrial dwelling, and even less, may become perceptible. But the highest magnifying power applied with advantage to the moon is considered to be 500, any power beyond that being found to interfere with other qualities necessary to be maintained for the purposes of observation. With this power an observer is enabled to see the moon as she would appear to the naked eye of a spectator at the distance of about 470 miles. But Mädler reckons the highest power advantageously used at only 300, which would require 790 miles to be substituted for the distance mentioned. He further states, that a German mile, which is equal to four English miles, is the utmost

limit of distance at which the keenest unassisted eye can distinguish human beings; and that to bring the moon to that distance would require a magnifying power of 51,000.

The dusky patches on the lunar disk were long supposed to be seas, as water reflects less light than land. Different tracts, therefore, received names in accordance with this idea, as the *Mare Imbrium*, "Sea of Showers," *Mare Nectaris*, "Sea of Nectar," *Mare Serenitatis*, "Sea of Serenity," the Pacific Ocean of the moon. These and other similar names are still retained, though founded upon a misconception; for, as before remarked, no trace of water is perceptible. Inequalities of all kinds are detected in the so-called seas; and other appearances identify them with the bright surrounding tracts. Nor is their shaded aspect solely the effect of depression below the level of the lighter parts. In fact, with a moderate magnifying power, various hues appear—pale grey, light green, and other tints. It is not unreasonable to suppose, that while referrible partly to a lower level, they intimate a difference in the substance of which the surface is composed, which may have unequal powers of reflecting light.

Nearly the whole surface of the moon, within and without the shaded parts, has a common character, which we should call Alpine in relation to the earth. The evidence of this rugged superficial structure is decisive, and not confined to one class of facts. A striking ocular proof of it is occasionally afforded in the occultation of a star. If the star is so situated, that it barely touches upon the moon's upper or lower limb in passing, the inequalities of the lunar surface are often declared by successive re-appearances of it after being obscured, evidently between mountains on the

edge of the disk. Professor Koch, Sir James South, Admiral Smyth, and Mr. Rumker, have recorded instances. The latter observed a star of the seventh magnitude, which appeared to run along the summits of the mountains on the moon's edge, by which it was eclipsed from time to time. It is also to be remarked, that when we look at the moon through a telescope, when she is horned, or gibbous, no regular line is seen bounding the enlightened and dark parts of the disk, as there would be if the surface were smooth. On the contrary, the line is marked with innumerable notches and breaks, as in the annexed representation of the lunar crescent, precisely the appearance which superficial irregularities will produce. In the unenlightened part also, but near the borders of the lucid surface, a number of bright points appear, like islands of light in a sea of darkness, which gradually join the illuminated face as the moon waxes, while others, before invisible, arise contiguous to the confines of light and darkness. Exactly the same appearances are exhibited during the phases of the waning moon, only that the bright points are gradually separated from the illuminated surface, and remain for some time visible on its confines in the dark region, till at last they also disappear. These are plainly the

Lunar Crescent.

tops of high mountains, which catch the sunlight earlier, and retain it longer, than the adjacent regions below them; just as the summits of the Alps are lit up morning and evening by the rising and setting sun, while the valleys at their base are wrapped in darkness. But the lunar mountains can be more palpably distinguished. Their forms are seen, with the shadows they project, from which their heights are estimated; and everywhere vast and deep valleys, gullies, and abysses, intersect them.

In proportion to the size of the satellite, mountains are much more extensively developed on the lunar surface than on the terrestrial. At least two-thirds of the presented hemisphere are occupied by them. In addition to being more numerous, they are also larger, loftier, and bolder, keeping the moon's inferior magnitude in view. Some rise to the height of 23,000 feet, nearly that of the culminating points of the Himalayan range. They are likewise remarkable for perpendicular descents, in comparison with which the most tremendous of our precipices are puny. Besides these peculiarities, the lunar mountains have the cup-shaped or crateriform outline strongly developed. The apparent type occurs on our globe in the craters of extinct and active volcanoes. But the examples are rare, and of limited size, whereas the whole surface of the moon is characterized by them; and the yawning throats of fiery respiration with which we are acquainted, are minute hollows when compared with the lunar formations. The extraordinary dimensions of most of them, with details of structure apparent on using high magnifying power, go far to destroy the analogy to volcanic formations; and certainly no trace of existing volcanic action on the moon has yet been discovered.

There are circular areas surrounded by elevated borders, varying in size from a few hundred yards in diameter to more than a hundred miles; and known, according to their magnitude, by the denomination of bulwark-plains, ring-mountains, craters, and holes. The areas are almost always depressed below the level of the general lunar surface; and hence the elevated borders, or ring-mountains, which inclose them, are much higher and precipitous on the inner than the outer side. They consist usually of several concentric ridges, more or less broken and abrupt, one of which is loftier than the rest, and is serrated with stupendous peaks. The floors of the interior spaces are plains, upon which isolated mountains of lesser height are scattered: in a few instances they are without inequalities; and in others, the flooring appears to be convex. Obviously these are features to which no parallel can be found on the earth. When the moon is full, the naked eye can discern towards the southern border of the disk, a little to the left, a lucid spot with streaks proceeding from it like rays. This is the most remarkable of the ring-mountains, called Tycho, after the celebrated Danish astronomer. It consists of a nearly circular inclosure, fifty-four miles in diameter, surrounded by a mighty ridge, steep as a wall on the interior side, and 16,000 feet high, while the height above the surrounding exterior surface is only 12,000 feet. The area is therefore depressed 4000 feet. Towards the centre of this huge pit, a precipitous rock with a pointed summit—the Sinai of Hevelius—shoots up to the height of 4,700 feet.

There are mountains arranged in chains, as on the surface of the earth, but this disposition is very exceptional. The most important example, called the

Apennines, runs in a straight line from north-east to south-west, and rises to a vast height, towards the centre of the disk. Its long shadows may be seen stretching over the Mare Imbrium, of which it forms the northern boundary, and from which the ascent is precipitous, while the descent on the opposite side is more inclined. At one extremity of the chain is Eratosthenes, termed by Mädler "the mighty key-stone of the Apennines." This is a ring-mountain, or rather bulwark-plain, as the interior is generally even. The inclosed space has a diameter of thirty-seven miles, and is depressed 3000 feet below the general surface. The encircling wall of rock rises 3000 feet on the exterior side, and has therefore an interior descent of 6000 feet. But the wall-surrounded plain is not featureless, for towards the centre a mountain towers at least 10,000 feet above the circular fence, so that its summit and sides are brightly lighted by the sunbeams, long before its base or any portion of the plain has received a ray. The adjoining Mare Imbrium, or Sea of Showers, one of the shadowy spots on the moon, has been selected by a recent writer for an inferential picture of lunar scenery.

"It is," he observes, "about seven hundred miles in extent every way. Let us cast our eyes around, and what do we see?—a boundless plain, or desert, stretching away as far as the eye can reach on every side, save in one or two points, where a chain of lofty mountains can be perceived, whose brilliant pointed summits, glittering in the sunbeams, just appear upon the distant horizon. The light that glares upon the plain is intense, and the heat of a tropical fierceness, for no cloud shelters us. By that light we may perceive, scattered over the plain, an infinite number of circular

pits, of different sizes and depths, varying from a few yards to some hundred in diameter, and sunk in the body or crust of the planet; some of them but a few feet, and others to an unknown and immeasurable depth. Above, the sky is black, out of which the sun gleams like a red-hot ball, and the stars sparkle like diamonds, for no atmosphere such as ours exists, to give, by its refractive and reflective powers, the delicious blue to its heavens, and the softened shade to its landscape. The lights and shades are indented upon its features deep and dark, or intensely bright; no softening away in the distance, no gentle and beautiful perspective, no lovely twilight—morning or evening—stealing over or away from the scene. All the shadows are abrupt, sudden; all the outlines sharp, clear; appearing startlingly near, even when really distant. No sound follows our footfall, or is ever heard in that silent place, for there is no atmosphere to conduct it; no fresh breeze blows on its mountain tops, sighs through its burning deserts, rustles through the brilliant green of forests, or waves over meadows; the silence of death broods over its arid wastes and rocky shores, against which no tides or billows break." The sketch thus drawn is supported in its main features by the testimony of the eye, and by the known law of causes and effects.

Recurring to the terrestrial relations of the moon, notice may be taken of various effects attributed to lunar influence, which are mostly misconceptions, of which the popular mind is not yet disabused.

The belief has long prevailed, and is still very general, that changes of the moon's phase, or her passage through the different quarters, influence the terrestrial atmosphere, and produce certain changes of the weather. This opinion was held in ancient times, for, according

to Theophrastus, the new moon brings bad weather, and the full moon fine. Submitted to the test of accurate observation, the idea is found to be completely groundless; nor is there any correspondence whatever between changes of the moon and vicissitudes of the weather. To account for an error so long accredited, Arago refers to the lack of impartial observations, and the involuntary tendency of the human mind to dwell upon facts favourable to its preconceived opinions, without any regard to those which are hostile to them. If a desired or obnoxious change of weather is coincident with a certain lunar change, and especially if this occurs more than once, the mind is struck by the coincidence, and leaves unnoticed, when the state of the weather has little personal importance, other similar changes of the moon which have not the same accompaniment.

Another error of long standing, and still prevalent, attributes to the moon an influence upon the felling of timber. It is held, that trees should not be cut down while the moon is increasing in phase, but when she is on the wane, otherwise the wood will not be found to be of good or durable quality. In the forest countries of Europe this practice is generally observed; and of so much importance was it once deemed in France, that the old forest-laws interdicted the felling of trees except during the wane of the moon. In the extensive catalogue of popular fallacies, there is scarcely one more extraordinary than the supposition, that a body at the distance of nearly 240,000 miles should exercise an influence propitious to wood-cutting during one half of the month, and unfavourable during the other. It has been tested, and shown to have no foundation.

The "red moon"—*la lune rousse*—has an ill repu-

tation in French rural districts, owing to a firm persuasion that its beams exercise a fatal influence upon tender plants. They are said to be reddened and cut off by exposure to them, while, if covered with straw, or provided with some other screen, no injury ensues. The moon, believed to be the cause of this mischief by shining chillingly and freezingly, is that of April and May, when the temperature is often only a few degrees above the freezing point. It is perfectly true, that exposed tender plants are injured or cut off on moonlight nights at that season; but it is not the moonlight that does this, for the very same effect would be produced in the absence of the moon, supposing the clouds to be absent likewise. When the night-sky is clear, heat is rapidly radiated from plants, while none being returned, their temperature may fall so as to cause them to be strongly frozen. But when clouds mantle the heavens, the radiation of heat into surrounding space is prevented; and as much being returned by reflection from the clouds as is given off by the plants, their temperature is not lowered to the freezing point. Now on moonlight nights the clouds must necessarily be more or less partial; and what is simply the effect of the unveiled sky has hence been referred to the visible luminary.

In all eastern countries, and many others, the moonlight is supposed to be deleterious to the human frame, as well as to promote the putrefaction of animal substances. Hence Virgil speaks of "the moon's doubtful and malignant light," *incertam lunam sub luce malignâ*, perhaps in allusion to these effects, though, as the poet of agricultural life, he may have referred to the injury to vegetation, popularly ascribed to the red moon. Messrs. Bennet and Tyerman remark in their Travels:

"Lunar influence seems to occasion phenomena of a very curious nature. It is confidently affirmed, that it is not unusual for men on board a ship, while lying in the moonlight, with their faces exposed to the beams, to have their muscles spasmodically distorted, and their mouths drawn awry; affections from which some have never recovered. Others have been so injured in their sight as to lose it for several months. Fish, when taken from the sea-water and hung up in the light of the moon during a night, have acquired such deleterious qualities, that, when eaten the next day, the infected food has produced violent sickness and excruciating pains. We have conversed with people who have been themselves disordered after having partaken of such fish. It is hazardous to touch on this subject: we repeat what we have heard from those who ought to be believed, and who would not affirm that of which they themselves were not persuaded." The above passage is written with praiseworthy caution. Mr. Carne, in "Letters from the East," also remarks:—"The effect of the moonlight on the eyes in eastern countries is singularly injurious. The natives tell you always to cover your eyes when you sleep in the open air. The moon here really strikes or affects the sight, when you sleep exposed to it, much more than the sun; a fact of which I had a very unpleasant proof one night, and took care to guard against it afterwards. Indeed, the sight of a person who should sleep with his face exposed to the moon at night would soon be utterly impaired or destroyed."

There is frequently some truth, mingled with error, in popular impressions, of which we have here an example. The observation is as old as the time of Plutarch, that exposure to the moonlight facilitates the

putrefaction of animal substances; and it is an undoubted fact, as believed by the fishermen of Naples, the West Indies, and South America, that fish in such circumstances speedily become unwholesome and unsaleable. If two pieces of meat are placed in an exposed situation on moonlight nights, the one screened, and the other uncovered, the latter will be tainted with putrefaction much sooner than the other. But it is not the light of the moon that inflicts the damage: it is the fine clear sky, which favours the radiation of heat, so that the exposed substance becomes colder than the surrounding air, dew is deposited, and the moisture is the cause of the decomposition. Hence we dry bodies in order to preserve them. In a similar manner most of the injurious effects attributed to sleeping in the moonbeams may be explained. The old French campaigners are familiar with the phrase *Hâle du bivouac*, by which a discolouration of the face is expressed consequent on sleeping in the open air. But they very well know that this takes place under an unclouded sky, whether the moon is present or absent; and that an artificial screen will answer the purpose of clouds in protecting them from it. With reference to injury to vision in the circumstances stated, it would be wonderful indeed if it did not take place. But the light of the moon has no power over the visual organs which does not belong in an inconceivably higher degree to that of the sun. Though lunar light, condensed with all the power of the largest burning lenses, has scarcely any appreciable calorific properties, and its chemical action is very feeble, yet a small portion of it affects the mechanism of the eye, and produces an instantaneous contraction of the pupil. Hence, accustomed as were the Jews to sleep under the canopy of heaven,

upon the housetops, at certain seasons of the year, we can appreciate the propriety of the imagery of the Psalmist: "The sun shall not smite thee by day, nor the *moon by night.*"

From time immemorial a mysterious connexion has been supposed to exist between lunar influence and some terrible maladies of mankind, especially mental derangement, epilepsy, and nervous disorders. Hippocrates and Galen, the two great physicians of antiquity, were both of this opinion; and it had disciples in Mead and Hoffman among the moderns. Our word *lunacy*, by which unsoundness of mind is meant, originated with the particular notion in question. The term is now almost discarded from medical phraseology; but it still keeps its place in popular speech and in the language of the law, for *lunatic* is the legal definition of one mentally disqualified from managing his own affairs. The opinion, as formerly held, which recognised a baleful influence directly exerted by the moon upon the human frame, chiefly when full, is now obsolete, or restricted to the class of ignorant quacks and knavish astrologers. At the same time, as tertian and quartan fevers have periodical fits of excitement, there is nothing abstractly improbable in other disorders observing a like periodicity, and, at longer intervals, strongly developing their symptoms. If this fact were established respecting insanity and epilepsy, which it is not, and if the interval corresponded to the time of the moon's revolution in her orbit, a case of coincidence would be proved, not of connexion. Much of what has been ascribed to a lunar cause is undoubtedly of human origin, the sheer result of nervous susceptibility, or pusillanimity of character. Lord Bacon is said to have fainted whenever there was a lunar

eclipse; and insanity may exhibit paroxysms at the full moon, owing to the strong lights and shadows of the night affecting the imagination.

Turning from popular fallacies to scientific determinations, the connexion of the moon with the tides of the ocean requires notice, as strikingly illustrating the positive utility of the companion orb. The regular flow and ebb of the great world of waters, one of its most interesting features, was known in the remotest antiquity to be in some way or other related to the moon. Kepler first conjectured the dependence of the fluctuations upon the attraction of that body; and Newton demonstrated them to be legitimate consequences of the laws of gravitation, explaining how the same tides occur simultaneously on the two sides of the earth opposite to the moon. In passing round the globe, the moon attracts the entire mass, or draws it towards her. But as the attractive force varies with the distance of the attracted object, according to a certain ratio, all parts of the earth are not acted upon with the same energy. Those nearest the moon are more strongly attracted than those which are more remote. At the same time, while the oceanic waters freely obey different attractions, owing to their mobility, the earthy substance of the globe is prevented from yielding to different impressions of the attractive force by the cohesion of its parts, and only gravitates towards the moon as a whole. It follows, therefore, that the waters immediately under the moon are drawn up in a protuberance, or high wave; and that the same effect takes place with the waters on the opposite side of the earth, by the whole solid globe being drawn away from them, being nearer than they to the attracting body, and more powerfully acted

upon. Thus two tides are produced at once at opposite extremities of the earth. The sun exerts a far more potent attractive sway upon our planet than the moon. But owing to the immense distance of the luminary, the inequality of the solar attraction on different parts of the earth is comparatively small, and the effect less. When the two bodies act in concert, as at full moon and change, we have the highest, or *spring* tides. When the solar and lunar attractions are in opposition, as at the quadratures, we have the lowest, or *neap* tides. By these fluctuations of the ocean, with the currents they create, its waters are prevented from becoming stagnant, its temperature is rendered more uniform, while navigation is facilitated, harbours are cleansed, ships are transported on rivers which would be otherwise unnavigable, and shell-fish are left by the retreating waves upon the strand, for the benefit of many an impoverished population.

Owing to the daily progress of the moon in her orbit from west to east, she rises at the mean rate of fifty minutes later every day. But in our latitudes an important deviation from the rule occurs, and is observed in corresponding latitudes of the southern hemisphere, at an opposite season of the year. That part of the lunar orbit lying in the signs Pisces and Aries makes a much less angle with our horizon than any other, so that as much of this section of it rises in two hours as the moon travels through in six days. Consequently, when so situated, there is but about twenty minutes difference per day in the time of rising for that number of days. Although this must be the case every month, yet it is only in the autumnal months that it occurs with the peculiarity of the moon being at the same time full. Hence we have the Harvest Moon, an important

benefaction to the husbandman, as the supplement of bright moonlight to the natural day gives him more available time to gather in the precious fruits of the earth, and to cheer him in the task. This fact was noted by persons engaged in agriculture long before it attracted the attention of astronomers; and was ascribed to the goodness of God, as having ordained it for their advantage.

Linked as is the satellite in the bonds of a close and enduring relationship to the earth—appointed to circulate round it while sharing its stately journey round the sun—it might fairly be inferred, that a useful ministry to the primary was contemplated in the provision, had we no express testimony to this effect. Yet while raising the tides of the ocean, relieving the gloom of night, facilitating the reckoning of time, and charming the senses with material beauty, it would be unwise to affirm confidently that these services are the highest purposes and final ends of Providence, in relation to the lunar world. We are not warranted in concluding it to be a mere manifestation of materiality, though, from its apparent physical constitution, and with limited understandings, it is utterly impossible for us to conceive with what kind of beings it can be occupied. The ways of God are higher than our ways, and his thoughts than our thoughts, as the heavens are high above the earth. Life exists in our own globe under the strangest conditions—conditions which are generally fatal to vitality. The Proteus Anguinus flourishes and propagates its kind in the dark waters of the Styrian caverns, which no ray of sunlight ever illumines. In unsunned abodes, and under enormous pressure, at immense depths in the ocean, marine animals are found. Fish can be frozen up with water into a solid

mass, and thawed into existence again, with their vital powers unimpaired; and toads survive through an unknown period, hermetically sealed up in the hollow of stones, deprived of all access to light, air, moisture, and food. But after all, there is nothing that ought to be startling to us in the idea, that the moon, or any other orb, is not at present fulfilling the high purposes which the earth is accomplishing. Our globe was once a desolate world as to organized existence, according both to sacred testimony and scientific observation. It was afterwards furnished with life in its lower forms, but was all the while advancing in a state of preparation to receive the higher, which were given when "God created man in his own image," and said to our first parents, "Be fruitful, and multiply, and replenish the earth, and subdue it."

CHAPTER VII.

THE LIGHTS OF HEAVEN DARKENED.

Grandeur of Occasional Phenomena—Eclipses—Consequences of the Planetary Movements—Law of Shadows—LUNAR ECLIPSES—Chaldean Period—Ancient Observations—Moon's Acceleration—Copper Colour of Eclipsed Moon—Total Disappearance of the Moon—The Landers in Africa—Sir R. Schomburgh at St. Domingo—SOLAR ECLIPSES—Total, Annular, and Partial—Chronicles of the Middle Ages—Eclipse of 1715—Observed from Salisbury Plain—Eclipse of 1842, described by Arago—Observed at Vienna—Eclipse of 1851—General Aspects of a Total Eclipse—The Darkness—Effect on Animated Nature—Luminous Ring—Red Prominences—Baily's Beads—Sudden Return of Daylight—" O Beautiful Sun."

WHILE we are constantly surrounded with grand and beautiful phenomena, impressing and delighting the reflective mind, there are natural events of occasional occurrence which are specially adapted to awaken feelings of awe and admiration. The blazing volcano belongs to this class, with the rush of the hurricane, and the peal and flash of the thunder-storm, the tempest-tossed ocean, auroral displays, and cometary apparitions. But perhaps there is no incident which so powerfully arrests attention as when the solar splendour is slowly impaired, and transiently blotted from the sky, by an interposing and previously invisible body, causing the earth to be darkened in the clear day. When not a cloud may be aloft, and no object is seen to account for the change, the magnificent orb, perhaps high in heaven, apparently loses part of its disk, gradually becomes more indented, and then totally disappears. But speedily a portion of the lustrous globe emerges from behind the dark interception, and the

whole circlet is again disclosed, shining with undiminished radiance. This transition from glory to gloom in the aspect of the luminary, with its unfailing recovery from the obscuration, vividly conveys to the mind the idea of stupendous power at work in the universe, and of the utter impotence of man to arrest the march of events. At the same time, the circumstances connected with a full solar eclipse render it in the highest degree impressive, and excite feelings of solemn interest in the breast of the spectator, though the natural cause of the event is so well understood, that we are able to predict the time of its occurrence with as much accuracy as the return of sunset and sunrise. All terrestrial objects assume a strange, unearthly, and almost spectral appearance, while the birds cease their song in the woods, the fowls seek their resting-places, the plants close their leaves, the brighter stars become distinct, and a chill is perceptible as on the approach of night.

> "'Tis as the pulse of life stood still,
> And nature made a pause."

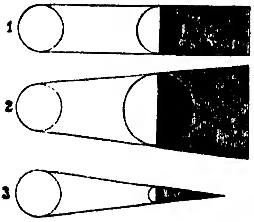
It is not surprising, therefore, that in primitive ages, as now in rude states of society, eclipses, both of the sun and moon, when of important extent, were regarded as alarming deviations from the established laws of nature, significant of great public calamities, and expressly designed to indicate to mankind the displeasure of a superior Power. Hence men have watched them with emotions of terror, their consciences accusing them; the strife of armies has been suspended by their occurrence; and guilty monarchs have trembled for the safety of their thrones. Thucydides, the historian, alludes to an eclipse of the sun which happened in the first year of the Peloponnesian war, towards the noon

of a summer day, when several stars were visible. The Athenian fleet was then ready to sail. Pericles, the commander, was on board his galley, and it required all his address to allay apprehensions, and proceed with the expedition, as the soldiers deemed the gloom an omen of disaster. Eighteen years afterwards, the Athenians totally lost their fleet and army in the harbour of Syracuse, owing to a lunar eclipse, which so terrified Nicias, that he was deterred from embarking at the proper moment. But while such events have long ceased to be objects of popular dread in civilized states, they have been of considerable practical utility in determining the difference of longitude of places on the earth's surface, and are even now of the highest interest as illustrating the physical constitution of the bodies in action.

Eclipses, transits, and occultations, are phenomena differing in circumstances, but identical in principle. They result from the fact of all the bodies of the solar system being in motion, with the exception of the sun itself, in consequence of which, some are occasionally brought into a position between others and the eye of a terrestrial spectator. In a transit, as previously explained, an interior planet passes between the earth and the sun; in an occultation, the moon passes between the earth and a planet or fixed star; in an eclipse, the moon passes between the earth and the sun, or the earth intervenes between the sun and moon.

As every planet, both primary and secondary, derives its light from the sun, which can only enlighten part of the orb at a time, it must project a shadow in a direction opposite to the luminary. This shadow is of course nothing but a privation of light in the space hid from the sun by the round opaque body of the planet,

the form and dimensions of which are regulated by the size of the planet and its distance from the sun. If the sun and planet were both of the same magnitude, the form of the shadow would be cylindrical, of the same diameter, and of unlimited length, as in fig. 1 of the diagram. If the planet were larger than the sun, the shadow would then resemble a truncated cone, of indefinite extent, as in fig. 2. But as all the planets are very inferior to the sun in volume, the shadows they cast converge to a point at a certain distance from their surfaces, dependent upon the circumstances just stated, as in fig. 3.



Such is the magnitude of the sun, that the shadow cast by each of the primary planets converges to a point long before it reaches any other planet, so that none of the primary planets can cause an eclipse to another. But any planet accompanied with satellites may produce this effect upon them, and also experience it from them. The cone of the earth's shadow is computed to extend into space upwards of 800,000 miles, which is equal nearly to four times the distance of the moon, but falls far short of the orbit of Mars. It has a mean diameter of 5700 miles at the moon's distance, and can therefore nearly three times comprehend her orb.

LUNAR ECLIPSES.

Eclipses of the moon occur when she is in opposition to the sun, or full; and are caused by the opaque globe

of the earth intercepting the solar light. The satellite is in this position during every revolution, and would be eclipsed every month, if her orbit lay exactly in the same plane with that of the earth. But the lunar path being inclined to the terrestrial, it is only when the moon, while in opposition, is at or near one of her nodes, or the points where her orbit crosses the plane of the ecliptic, that there is an eclipse. In other circumstances, the moon escapes the terrestrial shadow, either skirting it above or below. The nodes of the lunar orbit are perpetually shifting; and hence eclipses do not occur at regular intervals of time. But observation shows, that in 223 lunations, equal to rather more than 18 years, the moon's path intersects the plane of the earth's orbit at nearly the same points again, which causes the phenomena of eclipses to return within the interval in nearly the same order. The usual number occurring in the period is seventy, of which forty-one are solar, and twenty-nine are lunar. This cycle was known to the Chaldeans, who could only have arrived at its discovery by comparing together the records of eclipses extending through a long succession of years. It enabled them to predict their occurrence with considerable, though not with perfect accuracy; for if to the mean time of any eclipse, either of the sun or moon, the Chaldean period of about 18 years and 10 days is added,* it defines very nearly the recurrence of the same eclipse, with some slight alteration as to magnitude.

By means of lunar eclipses observed at Babylon in 721 B.C., and at Alexandria in 201 B.C., a solar eclipse, observed by Theon in the year 364 A.D., and two

* The period is 18y. 10d. 7h. 43m., or 18y. 11d. 7h. 43m., according as four or five leap years occur.

similar phenomena observed by Ibyn Jounis, at Cairo, towards the close of the tenth century, a slight acceleration in the mean motion of the moon has been ascertained, that is, that she now moves in her circuit with greater velocity than formerly. This inequality, still proceeding at a very slow rate, is the effect of a slow diminution in the eccentricity of the earth's orbit, owing to the action of the planets. In consequence of it, the moon, in the present day, is about *two hours* later in coming to the meridian than she would have been, had her monthly revolution been performed in the same time as when the earliest Chaldean observations were made. "It is a wonderful fact in the history of science," as Mr. Grant, the historian of Physical Astronomy, remarks, "that those rude notes of the priests of Babylon should escape the ruin of successive empires, and finally, after the lapse of nearly three thousand years, should become subservient in establishing a phenomenon of so refined and complicated a character." Halley was the first person who suspected the existence of this inequality, alluding to it in the year 1693; Mr. Dunthorne fully confirmed the suspicion, and fixed the amount of the acceleration in 1749; and Laplace satisfactorily explained the cause in 1787.

All lunar eclipses are completely visible in all parts of the earth where the moon is above the horizon, and the atmosphere is unclouded. They are everywhere also of the same magnitude, have the same commencement and end; and it is always the eastern side of the moon's disk that first plunges into the terrestrial shadow. But the time when they are seen varies according to the longitude; and thus they furnish a means of determining that important element. The

eclipse is total when the entire body of the satellite is immersed in the shadow, and partial when only a portion of the disk enters it. A total eclipse never exceeds two hours, and may be shorter than that period. It is generally the case, that the moon is distinctly visible when totally immersed in the earth's shadow, and simply changes colour, assuming a coppery or variously ruddy tint, amounting sometimes to a deep blood-red hue. The cause of this appearance was involved in obscurity till Kepler referred it to the refractive power of the earth's atmosphere, which turns the course of the solar rays passing through it, so as to fall upon the lunar orb. The peculiar colour assumed arises from the red rays, which have the least refrangibility, principally reaching her, the blue being absorbed by the terrestrial atmosphere; and the varying intensity of the tint depends upon the quantity of the red rays actually transmitted. But it occasionally occurs that the moon disappears totally. This is when the atmosphere is so loaded with vapours, that the red rays are absorbed as well as the blue. Wargentin, the Swedish astronomer, observed a lunar eclipse at Stockholm, in 1761, when the moon's body disappeared so completely, that not the slightest trace of any portion of the disk could be discerned, either with the naked eye or with the telescope.

Eclipses of the moon, though not so impressive as those of the sun, are often very remarkable within the tropics, much more so than in our own latitude, owing to the gloriously bright nights, and they are still viewed with awe and consternation by the ignorant native races. The Landers, during their stay at Boossa, in Central Africa September 2, 1830, witnessed a striking scene. " The early part of the evening had

been mild, serene, and remarkably pleasant. The moon had arisen with uncommon lustre, and, being at the full, her appearance was extremely delightful. It was the conclusion of the holidays, and many of the people were enjoying the delicious coolness of a serene night, and resting from the laborious exertions of the day. But when the moon became gradually obscured, fear overcame every one. As the eclipse increased, they became more terrified. All ran in great distress to inform their sovereign of the circumstance, for there was not a single cloud to cause so deep a shadow, and they could not comprehend the nature or meaning of an eclipse. Groups of men were blowing on trumpets, which produced a harsh and discordant sound; some were employed in beating old drums, others again were blowing on bullocks' horns. The diminished light, when the eclipse was complete, was just sufficient to enable us to distinguish the various groups of people, and contributed in no small degree to render the scene still more imposing. If an European, a stranger to Africa, had been placed on a sudden in the midst of the terror-struck people, he would have imagined himself among a legion of demons, holding a revel over a fallen spirit."

"It was a lovely tropical night," writes Sir R. Schomburg, of a total lunar eclipse at St. Domingo, January 6, 1852, "no cloud to be seen, and the stars shone brightly, without much twinkling. The light which the moon shed while advancing towards the zenith was so clear, that moderate-sized print could be read with facility. The shadow of the earth approached the luminary, and gradually stole over the bright fair moon. I stood alone upon the flat roof of the house which I inhabited, watching the progress of the eclipse,

I pictured in imagination the lively and extraordinary scene which I once witnessed in the interior of Guiana, among the untutored and superstitious Indians. How they rushed out of their huts when the first news of the eclipse came, gibbered in their tongue, and, with violent gesticulations, threw up their clenched fists towards the moon. When, as on this occasion, the disk was perfectly eclipsed, they broke out in moanings; and sullenly squatted upon the ground, hiding their faces between their hands. The females remained during these strange scenes within their huts. When, shining like a sparkling diamond, the first portion of the moon that had disencumbered itself from the shadow became visible, all eyes were turned towards it. They spoke to each other with subdued voices; but their observations became louder and louder, and they quitted their stooping position as the light increased. When the bright disk announced that the monster which wanted to stifle the Queen of Night had been overcome, the great joy of the Indians was expressed in that peculiar whoop which, in the stillness of the night, may be heard for a great distance. The women and children then joined the men in their merry gambollings."

SOLAR ECLIPSES.

Eclipses of the sun are occasioned by the opaque body of the moon passing between the earth and the sun, and therefore occur when she is in conjunction, or at the instant of new moon. But while in this position, the satellite will not directly interpose and intercept the solar light, unless she is at or near one of the nodes of her orbit. If the centre of the moon comes in a direct line between the centres of the earth

and the sun, and if at the same time the apparent diameter of the moon exceeds the apparent diameter of the sun, then the eclipse will be *total*, the solar disk being entirely concealed from the eye of the spectator. In such circumstances, the cone of the lunar shadow is projected upon an area of the earth, never exceeding about 175 miles in breadth, which travels over a belt of the surface, in consequence of the earth's and moon's motion. But the condition stated is not always fulfilled, owing to the eccentricity of the lunar orbit, which causes the moon to vary in her distance from the earth, and consequently in her apparent diameter. Hence, if she is at her greatest distance from the earth when central interposition takes place, the moon will not be able to cover the entire face of the sun, and the eclipse will be *annular*, a slender ring of dazzling solar light being exposed to view around the dark interposing body. A *partial* eclipse ensues, when the moon does not pass centrally over the sun, but overlaps merely a portion of the disk. Solar eclipses, reckoning from the beginning to the end of the obscuration, may last for several hours. But the time of the totality is always limited to a few minutes. They always begin on the western, and end on the eastern edge of the luminary.

Though solar eclipses occur more frequently than lunar, yet a total eclipse of the sun, to any part of the earth's surface, is a very rare event; and its recurrence to the same place is one of the rarest of all natural incidents. Halley remarked, in a paper on the total eclipse of the 3d of May 1715, the reign of George I., which was visible at London, that there had not been one, visible there, since the 20th of March 1140, the reign of Stephen, an interval of nearly six centuries.

Under the latter date the Saxon Chronicle records:— "In the Lent, the sun and the day darkened about the noontide of the day, when men were eating; and they lighted candles to eat by. That was the thirteenth day before the calends of April. Men were very much struck with wonder." William of Malmesbury also states of the same event, that "while men were sitting at their meals, the darkness became so great, that they feared that the ancient chaos was about to return; and upon going out immediately, they perceived several stars about the sun." The time of a total eclipse on the 17th of June 1433, visible in Scotland, was long remembered by the peasantry as the *Black Hour*. It was of an unusual kind, as, according to calculation, the sun was then nearly at its farthest point from the earth, while the moon was not far from her nearest. In a similar manner, the name of the *Black Saturday* was given to the day of a total eclipse in the year 1598, when the lunar shadow passed over the border counties of England and Scotland; and *Mirk Monday*, denoting the era of another, in 1652, visible in Scotland, was a familiar phrase long after the eclipse itself had been forgotten. A local chronicler states:— "In February 1652, there was a great eclipse of the sun about nine hours of the forenoon, on a Monday. The earth was much darkened: the like, as thought by astrologers, was not since the darkness of our Lord's passion. The country-people, tilling, loosed their ploughs, and thought it had been the latter day: some of the stars were seen, and the birds clapped to the ground."

During the eclipse already referred to, witnessed by Halley at London in 1715, the planets Jupiter, Mercury, and Venus were seen, as well as the stars Aldebaran and

Capella. "I forbear," he observes in his descriptive paper, "to mention the chill and damp which attended the darkness of this eclipse, of which most spectators were sensible and equally judges. Nor shall I trouble you with the concern that appeared in all sorts of animals, birds, beasts, and fishes, upon the extinction of the sun, since ourselves could not behold it without some sense of horror." Louville, who came from Paris to observe the phenomenon, states, in his report to the Academy of Sciences, that a little before the sun was totally eclipsed, the cocks of London began to crow as at daybreak; that they were silent during the total obscuration; and that the sun had no sooner re-appeared than they commenced to crow with greater vivacity than before. In other parts of the country more favourable for observation, as many as twenty stars were seen by the naked eye. Halley has left on record a striking description of the scene, received from one of his friends, supposed to be Dr. Stukeley, who stationed himself upon an eminence on Salisbury Plain. "I chose," he remarks, "for my point of observation a place called Haradow Hill, two miles from Amesbury, and east of the avenue of Stonehenge, of which it closes the vista. In front is that celebrated edifice upon which I knew that the eclipse would be directed. I had, moreover, the advantage of a very extensive prospect in every direction, being on the loftiest hill in the neighbourhood, and that nearest to the centre of the shadow. I had with me Abraham Sturgis and Stephen Evans, both natives of the country, and able men. My two companions looked through blackened glasses, while I made some reconnaisance of the country.

"It was half past five by my watch when they

informed me that the eclipse was begun. We watched its progress, therefore, with the naked eye, as the clouds performed for us the service of coloured glasses. At the moment when the sun was half obscured, a very evident circular rainbow formed at its circumference, with perfect colours. As the darkness increased, we saw the shepherds on all sides hastening to fold their flocks, as they expected a total eclipse of an hour and a quarter duration. When the sun assumed the appearance of the new moon, the sky was tolerably clear, but it was soon covered with deeper clouds. The rainbow then vanished. Scarcely had we time to count ten, when Salisbury spire, six miles to the south, was enveloped in darkness. We lost sight of the sun, whose place till then we had been able to distinguish in the clouds, but whose trace we could now no more discover than if it had never existed. By my watch, which I could scarcely discern by some light that reached us from the north, it was thirty-five minutes past six. Shortly before, the sky and the earth had assumed, literally speaking, a livid tint, for it was a mixture of black and blue, only the latter predominated on the earth and at the horizon. There was also much black diffused through the clouds, so that the whole picture presented an awful aspect, that seemed to announce the death of nature.

"We were now enveloped in a total and palpable darkness, if I may be allowed the expression. It came on rapidly, but I watched so attentively, that I could perceive its progress. It came upon us like a great black cloak thrown over us, or like a curtain drawn from that side. The horses we held by the bridle seemed deeply struck by it, and pressed closely to us with marks of extreme surprise. As well as I

could perceive, the countenances of my friends wore a horrible aspect. It was not without an involuntary exclamation of wonder I looked round me at this moment. It was the most awful sight I had ever beheld in my life."

Great interest was excited by the total eclipse of July 8, 1842, owing to the zone of visibility in the southern provinces of France, Germany, and Russia, and the north of Italy, being so favourably situated with reference to the seats of European science. Astronomers stationed themselves at various points in the track of the lunar shadow; as, M. Arago at Perpignan, M. Valz at Marseilles, M. Petit at Montpellier, Miss Pinnaud at Toulouse, Mr. F. Baily at Pavia, Mr. Airy, the Astronomer Royal, at the Superga, near Turin, M. Pioala at Lodi, M. Carlini at Milan, MM. Santini and Centi at Padua, MM. Schumacher and Littrow at Vienna, and MM. Otto Struve and Schidlowsky at Lipesk. The morning was favourable for observation. M. Arago has thus graphically described the occurrence:—"At Perpignan, persons who were seriously unwell alone remained within doors. As soon as day began to break, the population covered the terraces and battlements of the town, as well as the little eminences in the neighbourhood, in hopes of obtaining a view of the sun as he ascended above the horizon. At the citadel we had under our eyes, besides groups of citizens established on the slopes, a body of soldiers about to be reviewed.

"The hour of the commencement of the eclipse drew nigh. More than twenty thousand persons, with smoked glasses in their hands, were examining the radiant globe projected upon an azure sky. Although armed with our powerful telescopes, we had hardly

begun to discern the small notch on the western limb of the sun, when an immense exclamation, formed by the blending together of twenty thousand different voices, announced to us that we had anticipated only by a few seconds the observation made with the unaided eye by twenty thousand astronomers equipped for the occasion, whose first essay this was. A lively curiosity, a spirit of emulation, the desire of not being outdone, had the privilege of giving to the natural vision an unusual power of penetration. During the interval that elapsed between this moment and the almost total disappearance of the sun, we remarked nothing worthy of relation in the countenances of so many spectators. But when the sun, reduced to a very narrow filament, began to throw upon the horizon only a very feeble light, a sort of uneasiness seized upon all: every person felt a desire to communicate his impressions to those around him. Hence arose a deep murmur, resembling that sent forth by the distant ocean after a tempest. The hum of voices increased in intensity as the solar crescent grew more slender: at length the crescent disappeared, darkness succeeded light, and an absolute silence marked this phase of the eclipse, with as great precision as did the pendulum of our astronomical clock. The phenomenon, in its magnificence, had triumphed over the petulance of youth, over the levity which some persons assume as a sign of superiority, over the noisy indifference of which soldiers usually make profession. A profound stillness also reigned in the air: the birds had ceased to sing.

"After an interval of solemn expectation, which lasted about two minutes, transports of joy, shouts of enthusiastic applause, saluted with the same accord,

the same spontaneous feeling, the first reappearance of the rays of the sun. To a condition of melancholy produced by sentiments of an indefinable nature, there succeeded a lively and intelligible feeling of satisfaction, which no one sought to escape from, or moderate the impulses of. To the majority of the public the phenomenon had arrived at its term. The other phases of the eclipse had few attentive spectators beyond the persons devoted especially to astronomical pursuits."

An observer at Vienna states, that as the eclipse proceeded, "a perceptible stillness crept into the air, and flights of swallows flew wildly and restlessly through the darkening atmosphere. But all this gave no intimation of the effect that was to follow. Had I not been aware that an eclipse was in progress, I might only have imagined that the morning was chill and vapoury. But now approached the important moment. A heavy bell tolled at intervals from the city, like the funeral knell of our beautiful orb of light and life. Yet a moment, and on a sudden an event took place, unexpected and sublime. The whole aspect of heaven and earth underwent a change, with regard to light, shade, colouring, every thing; and the instant that preceded the total eclipse resembled in nothing, and gave no idea of that which followed it. Round the black sun appeared a halo of whitish light, defining clearly and strongly the obscured orb. In some places this halo extended into longer gleams, forming altogether a faint glory, like that with which painters surround the head of Christ. It was not so generally dark as I had supposed it would have been, though the reckoner declared there was a time when he could not discern the second-hand of the chronometer; but

the sudden diminution of light, at the moment of total obscuration, was strange and startling."

The whole population of Vienna, as in other places in the path of the moon's shadow, was early on the alert, except the invalid and infirm. Thousands thronged the ramparts of the city. Schumacher, from Denmark, occupied the tower of the observatory alone; Littrow, the local astronomer, was in a spacious inclosure of the Botanical gardens, at the head of a small knot of *savans*. A mound, amply provided with all sorts of telescopes and chronometers, was the head-quarters. It commanded an extensive sweep of sky and landscape—the long line of crowded ramparts on the one hand, with the city and the blue Carpathian mountains beyond it, in the distance on the other. As the critical moment of total obscuration approached, the most perfect stillness reigned. Every spectator was subdued by the important interval, with its strange and sombre shades, perceptible chill, heavy dew, and the altered physiognomy of heaven and earth. After little more than two minutes, in an instant the day was restored to nature; and in spite of the demonstrations of astronomy, every one felt as though something had been recovered in danger of being lost. The fidelity with which this widely-observed eclipse answered to previous calculations respecting the time of its occurrence, made a powerful impression upon the popular mind, with reference to the advanced state of science, the regularity which marks the great clock-work of the universe in its movements, and the omnipotence of the Artificer.

Another total eclipse took place on the 28th of July 1851, when the lunar shadow passed over the north of Europe, and a considerable number of our countrymen

repaired to different places in its path, for systematic observation. Mr. Airy stationed himself at Gothenburg, Mr. Dunkin at Christiania, Messrs. Humphreys and Miland at Christianstad, Messrs. Stephenson and Andrews at Fredericsvaarn, Mr. Lassel at Trolhätten Falls, Messrs. Hind and Dawes near Engelholm, and Dr. Robertson of Edinburgh, with Dr. Robinson of Armagh, on an island off the coast of Norway. Some peculiar appearances observed in eclipses were verified upon this occasion. The next great solar eclipse visible in England occurred on the 15th of March 1858, which, though not total, will only be exceeded in magnitude during the present century by that of August 19, 1887. It was central and annular to a line of country passing from Dorsetshire to the Wash, a little to the north of the towns of Sherborne, Marlborough, Oxford, Buckingham, and Wisbeach. The gloom was very perceptible in London, but a clouded sky almost everywhere precluded observation.

Some leading circumstances connected with the occurrence of a full solar eclipse may now be noticed in detail.

1. The great feature of the occasion is of course the *sudden and peculiar gloom* thrown over the face of nature at the instant of total obscuration. The darkness disappoints popular expectation in its intensity, being never so great as commonly supposed. It appears, also, not to be uniformly profound, on comparing the records of different eclipses, and of the same eclipse at different stations. This arises, doubtless, from the varying condition of the atmosphere at different times and places. But the gloom is sufficiently deep in general to prevent a person of ordinary eyesight from reading. At Geneva, in 1706, the

members of the council, who were deliberating when an eclipse came on, rose from their seats, because they were unable to read or write. The brighter stars and planets appear, and lamps and candles are nearly as distinct as at night. It was remarked at Venice, in 1842, with respect to a steamer passing on the lagunes during the total obscuration, that the column of black smoke from the funnel was no longer visible, while the sparks of fire carried up with it were seen, and appeared to be isolated.

Mr. Airy remarked, that the illumination afforded during this eclipse was so small, that he could with difficulty read the divisions on the watch-plate, which was within eight inches of his eye. And referring to the subsequent occasion in 1851, he states, "I must advert to the darkness. I have no means of ascertaining whether the darkness really was greater in the eclipse of 1842. I am inclined to think, that in the wonderful, and I may say appalling obscurity, I saw the grey granite hills within sight of Hvaläs more distinctly than the darker country surrounding the Superga. But whether because, in 1851, the sky was much less clouded than in 1842, so that the transition was from a more luminous state of sky to a darkness nearly equal in both cases, or from whatever cause, the suddenness of the darkness in 1851 appeared to be much more striking than in 1842. My friends who were on the upper rock, to which the path was very good, had great difficulty in descending. A candle had been lighted in a lantern about a quarter of an hour before the totality; and Mr. Haselgren was unable to read the minutes of the chronometer-face without having the lantern held close to the chronometer."

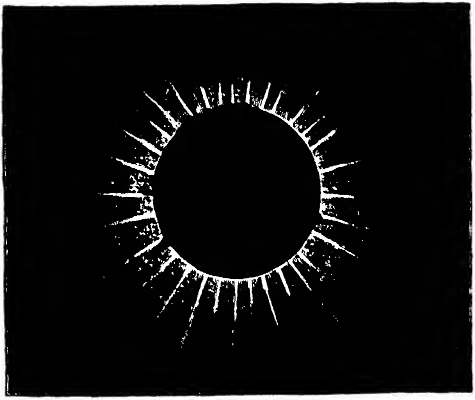
All observers agree in representing the gloom as entirely different from that of the natural night—a faint, indescribable, and unearthly light being afforded, which gives to the human countenance a livid aspect, painful to contemplate, throws upon surrounding objects unnatural hues, and clothes earth and sky with an appalling appearance. Mr. Hind states, of the obscuration in 1851, that "the entire landscape was overspread with an unnatural gloom; persons around him assumed an unearthly cadaverous aspect; the distant sea appeared of a lurid red; the southern heavens had a sombre purple hue; the northern heavens had an intense violet, and appeared very near. On the east and west of the northern meridian bands of light of a yellowish crimson colour were seen, which gradually faded away into the unnatural purple of the sky at greater altitudes, producing an effect that can never be effaced from the memory, though no description could give a just idea of its awful grandeur."

2. Many interesting observations have been made upon the effect produced by a total eclipse upon *animated nature*, from which it appears, that both animals and plants comport themselves as at the ordinary transition from day to night. In 1706, at Montpellier, it was noticed that the bats flew about as at dusk; the fowls and pigeons betook themselves in great haste to their resting-places; the little birds in cages were silent, and put their heads under their wings; and the animals which were at labour stood still. In many instances, during the eclipse of 1842, according to Arago, the horses employed in the fields halted all at once when it became total, lay down, and obstinately refused to move, in spite of the whip. One of his friends had five healthy linnets in a cage, three of

which died during the sudden darkness. At Montpellier the bats left their retreats, thinking that the night was come. An owl was seen to leave the tower of St. Peter, and fly over a part of the town; the swallows disappeared; the fowls went to roost; and a herd of cattle in a field formed themselves into a circle, as if to resist an attack. At Venice, swallows were caught in the streets by hand, overpowered with terror. Yet in all parts it was remarked that the horses employed in the diligences continued their course, without appearing to be in the slightest degree affected by the event. The effect of the obscurity upon those plants which usually close up their leaves during the night was very apparent at Vienna, Milan, and in various parts of France.

3. It is invariably the case, when the disk of the sun is completely hidden by that of the moon, that the body of the latter appears surrounded by a *corona*, or *luminous ring*. This is one of the most interesting features of a total eclipse. It appears to have been first mentioned with reference to an eclipse in A.D. 95, which was supposed to announce the death of the emperor Domitian. "In the heavens," says Philostratus, "there appeared a prodigy of this nature: a certain *corona*, resembling the Iris, surrounded the orb of the sun, and obscured his light." Plutarch seems to have been familiar with the appearance, for he states, that "although the moon should at any time hide the whole of the sun, still the eclipse is deficient in duration, as well as amplitude, for a peculiar effulgence is seen around the circumference." The ring has been observed at different times to vary in breadth and brightness, owing, probably, to varying conditions of the terrestrial atmosphere. It fades off

imperceptibly outwards; and has this radiating aspect occasionally very decided. The generally received opinion respecting the luminous ring is, that it has no physical connexion with the moon, but is entirely solar, and arises from the presence of an atmosphere about the sun.



ECLIPSE.

4. In the ring of light around the moon during the time of total obscuration *reddish spots* or *prominences* are often seen, in a fluctuating condition, varying in number, and occasionally exhibiting very deep tints. They have been compared by observers to beautiful sheaves of flames, and to the rose-coloured snowy tops of the Alpine mountains when illuminated by the rising or setting sun. On one occasion it was remarked, so deep were the tints, that if the dark disk of the moon had been uniformly bordered with these

prominences, it would have resembled "a box of ebony garnished with rubies." They were very conspicuous during the eclipse of 1851. The colour is spoken of by spectators at different stations as a full lake-red, a brilliant lake, a splendid pink, a bright rose-red, a rich carmine, and a full rose-pink. Some of the chief projections looked like burning volcanoes, with dull streams of cooling lava on the sides. Astronomers are generally agreed that these appearances are in no way connected with the moon, but are probably clouds suspended in the atmosphere of the sun, which absorb all the rays of the spectrum, with the exception of the red ones.

5. A feature, which seems to be totally distinct from the preceding, was particularly noticed and described by the late Mr. F. Baily. When the disk of the sun has been reduced by the advancing disk of the moon to a thin crescent, and complete obscuration approaches, instead of a fine and regular line of light being exhibited, a succession of brilliant points appear, separated by dark spaces, resembling a *number of beads* strung upon black thread. Hence the name of "Baily's beads," applied to the phenomenon. But Baron de Zach distinctly observed the appearance at a prior date, on the occasion of the eclipse of 1820, at Bologna. "Before," he remarks, "the contact of the two limbs was effected, there was visible, not a continuous thread of light, but a number of luminous points, resembling a row of so many pearl beads, separated by dark intervals. This beautiful phenomenon lasted only an instant, for the contact of the limbs, and the total disappearance of the last trace of light, was instantaneous." The beads were very perceptible during the eclipse of 1851. Different observers compared them to globules of mercury

on the edge of the moon, and to a necklace of diamonds. It is supposed that projections on the edge of the lunar disk coming into contact with the margin of the sun, form the dark spaces, while the solar light, shining for the moment through the vacuities between them, produces the brilliant beads.

6. It is only for a comparatively brief period that the sun is wholly hidden behind the dark body of the moon. The totality can only last at the longest about seven minutes, even at places close to the centre of the lunar shadow, and is commonly shorter. All that is popularly impressive in the spectacle is confined to this interval; for so long as the smallest portion of the lustrous orb is visible, there is considerable light. Nature simply looks sobered and saddened till the moment of complete obscurity arrives. Then the diminution of light is strongly marked, and a spectre-like aspect is stamped upon every object—sky, clouds, trees, mountains, streams, buildings, animals, and man—producing an effect which is unexpected, strange, and awful. But equally sudden and startling is the recovery of nature from its unwonted appearance upon the emergence of the first ray from behind the eclipsing body. It darts forth with a velocity comparable to the swiftest movement of which we are cognisant, the flight of an arrow, the flash of the lightning; and with such brilliant effect, that in an instant the night is turned to day.

"Oh, beautiful sun!" Such was the exclamation of a poor child belonging to the commune of Sièyes, in the Lower Alps, while tending a flock, on a bright and lovely morning of a summer day. What led the lone one thus to apostrophize the luminary? It was early, scarcely past six o'clock. The sun had risen high in

heaven, dissipating the vapours, and promised to reign in unclouded splendour throughout the day. But gradually his light darkened, until it wholly disappeared, and a black orb took possession of the glowing disk, while the air became chill, and a mysterious gloom invested every object. Terrified by the circumstance, the child began to weep, and called loudly for help. Her cries speedily drew some friends to the spot, but they were in an equal state of alarm. Tears were still flowing, when the luminary again sent forth an enlivening ray, which instantly divested the landscape of its portentous and alarming aspect. Reassured by the returning radiance, the child involuntarily crossed her hands, and exclaimed in the *patois* of the district, "*O, beau souleau!*" The total eclipse of 1842 had come and gone, but no information of the event had reached the secluded rustics to prepare them for it. Hence the terror of the shepherdess and the alarm of the peasantry. Ignorant nations have idolized the luminary, philosophers have striven to understand the constitution of the orb, poets have celebrated the brightness of the beams, and painters have done their best to put on canvas their diversities of light But no tribute more striking was ever paid to the monarch of the skies than the peasant girl's expression as the solar radiance returned, at once legitimate, unaffected, and truthful, "Oh, beautiful sun!"

Yet is there a more excellent glory than the material splendour in the heavens—a better light than that which discloses the scenery of terrestrial nature. It is not obvious to the senses, but enlightens the mind; it meets not the outward eye, but is recognised by faith; it beams not for the purpose of guiding the footstep aright, but of leading the soul to a sure

habitation and a quiet resting-place; it knows nothing of obscuration or eclipse, but is a perpetual source of comfort and safety to those who abide by its direction. "I am the light of the world," said the Saviour to his hearers: "he that followeth me shall not walk in darkness, but shall have the light of life." His cross has purchased the gift of eternal life for all believers; his word reveals the way to his inheritance; his grace prepares the spirit for its enjoyment; and to all his followers the statement applies, in the full blessedness and amplitude of its meaning, "The Lord shall be unto thee an everlasting light, and thy God thy glory. Thy sun shall no more go down; neither shall thy moon withdraw itself."

CHAPTER VIII.

MARS—THE PLANETOIDS—METEORS, AND METEOR PLANETS

Exterior Planets—Mars—Ruddy Colour—Varying Appearance—Elements of the Planet—Analogy to the Earth—The Planetoids—Great Gulf between Mars and Jupiter—Inference of Kepler—Bode's Law—Meeting of German Astronomers—Discovery of Ceres, Pallas, Juno, and Vesta—Recent Discoveries of Small Planets—The Planet-Finders Characteristics of the Small Planets—Hypothesis of Olbers—Meteors and Meteorites—Shooting-Stars—Leading Features of their Apparition—Loud Explosions—Meteoric Showers—Mediæval Chronicles—Grand Shower of 1799—Extraordinary Display of 1833 Conclusions relative to it—Fall of Bodies to the Earth—Examples of Aërolites—Their Chemical Analysis—Presumed Volcanic, Lunar, and Atmospheric Origin—Planetary Theory.

We now come to the superior or exterior planets, those which never pass between us and the sun, but wander to the greatest angular distance from the central sphere, being sometimes seen on the meridian at midnight, rising at sunset, and setting at sunrise. Mars, the nearest of these bodies, is readily distinguished by a ruddy appearance, noticed from remote antiquity; and probably this fiery hue originated the name, derived from the god of war, in the ancient mythology. The dark red light reflected is generally imputed to a very dense and extensive atmosphere, which, like our own, is penetrated by the yellow and red rays more easily than by the blue and violet. But some consider the cause to be geological, conceiving the general soil to be thus coloured, like the red sandstone districts of the earth, but more decidedly. The planet is remarkable for striking changes of aspect, sometimes shining as a dazzling orb with a large diameter, and then gradually dwindling to an almost imperceptible speck. This is

owing to the great change in its distance from us, for it varies from under fifty millions of miles to nearly five times that extent, or to upwards of two hundred and thirty millions. Thus, when the planet and the earth are on the same side of the sun, it is clear they will be nearer by the entire diameter of the terrestrial orbit, than when the two bodies are in opposition to each other. Hence the change from a faint hazy appearance to a lustre which, under the most favourable circumstances, rivals the glow of Jupiter. On the 27th of August 1719, when the planet was at the nearest point to the earth, and at the same time in perihelion, or at the nearest point to the sun, its brightness was so great as to alarm the ignorant; and by some it was mistaken for a comet or a new star.

Mars has a diameter of 4100 miles, nearly one-half less than that of the earth. He revolves round the sun at the mean distance of 145,000,000 of miles, and accomplishes a revolution in 687 terrestrial days, equal to nearly two years. By observation of spots upon the surface, his rotation upon a fixed axis has been nicely ascertained to be performed in rather more than twenty-four hours and a-half. Thus intervals of day and night are experienced similar in length to our own; and as the axis has about the same inclination to the plane of the orbit, as in the case of the earth, there is the same succession of seasons. Under powerful telescopic examination, well-defined seas, of a greenish hue, and continents, are observed, with the geographical lines of demarcation beautifully distinct. But having no attendant moon to attract the waters, the oceans must be almost tideless. Bright appearances at the poles, changing in magnitude and luminosity, are supposed to be the light reflected from masses of snow and ice

accumulated in the polar regions. The changes exhibited are obviously connected with the summer and winter seasons as their cause. When emerging from the darkness of their long winter, the bright spots are the most distinct, and at the close of the long summer they are the least perceptible, as if the ice and snow had partially melted under the dissolving action of the solar rays. These are the chief facts known respecting our "celestial cousin-german," as Mars has been called, owing to the strong analogy between him and the earth.

THE PLANETOIDS.

It was long remarked with surprise, that on proceeding outwardly in the system, the interplanetary spaces are proportionate to each other till we come to the orbit of Mars, where an apparent interruption to the general order occurs. Thus Mercury and Venus are separated by about 30 millions of miles; Venus and the Earth by 27 millions; the Earth and Mars by 50 millions. But the orbit of Jupiter, the next of the primary planets, is nearly 350 millions of miles beyond that of Mars, or considerably more than twice the whole distance of Mars from the sun. This seeming anomaly arrested the attention of Kepler, who sagaciously inferred the existence of an unknown planet in the enormous gap, boldly predicted its discovery, and assumed its reality in theorizing upon the system. The idea was strongly revived towards the close of the last century by the following curious but purely empirical law, detected by Professor Bode of Berlin:—

Write the series	0	3	6	12	24	48	96	192, etc.
Add to each term . . .	4	4	4	4	4	4	4	4 .
The sums are	4	7	10	16	28	52	100	196

If the third sum, 10, be taken to represent the earth's distance from the sun, the remaining terms of the series will represent very nearly the distances of the other planets. Thus,

4	7	10	16	28	52	100	196
Mercury	Venus	Earth	Mars	—	Jupiter	Saturn	Uranus.

The fifth term in the series is blank, and marks the immense interval between the orbits of Mars and Jupiter, where it was supposed a planet ought to be, and would be discovered. Bode's law teaches, that if, proceeding through the system outwards from the sun, the interval between planet and planet is measured, it will be found that each successive interval is about twice as great as the one before, and only half that of the succeeding one, subject to the striking exceptional case referred to. But as this numerical harmony is not fulfilled with absolute precision, it is regarded as a striking coincidence, rather than an astronomical law.

So strongly did the great leap from Mars to Jupiter impress the German astronomers with the idea of a planet revolving in the intermediate region, that, at a meeting held in Lilienthal in the year 1800, it was determined to raise the "hue and cry" regularly after the long-suspected world. Accordingly, an association of twenty-four practical observers was formed; and the whole zodiac was divided into twenty-four zones. Each zone was committed to a particular observer, whose duty it was to scrutinize the province assigned him, note the telescopic fixed stars in it, and detect, if possible, any moving body among them. The eminent Schroeter was appointed president of this association, and Baron de Zach secretary. It is obvious, that by noting down with the utmost precision the number, magnitude, and relative places of all the stars in a given

region, any subsequent changes might be easily recognised upon the region being re-examined. It would be exactly the same as if a daguerreotype picture of that part of the heavens had been taken, which, being compared with another picture taken twelve months afterwards, the comparison of the two would immediately show if any object had wandered from its place, or any stranger had intruded.

Piazzi, the Italian astronomer, though not a member of the planet-seeking fraternity, was the first to justify the anticipations indulged. This was at Palermo, in Sicily, on the new-year's day of 1801, the first of the nineteenth century. While carefully examining a part of the constellation Taurus, he observed a small star not marked in any catalogue, which, on the following evening, had sensibly changed its place, and which he at first announced as a comet, misled by a hazy appearance. It was then approaching the sun, and soon ceased to be visible. But on extricating itself from the solar rays, its planetary character was revealed. The new body received the name of CERES, after the titular goddess of Sicily. King Ferdinand wished to commemorate the event by a gold medal bearing the astronomer's likeness; but Piazzi suggested that the sum to be expended might be more usefully applied to the purchase of a large telescope. The orbit of Ceres exactly answered to the place where a planet was presumed to be absent. But while the whole astronomical world was delighted with this verification of its conjectures, the result was somewhat disappointing and perplexing. The new planet proved an anomalous object in the system, being of excessively minute size, and having an orbit very considerably exceeding in its inclination to the ecliptic that of the old planets.

Another discovery of a similar nature, but more startling, was speedily made. On the 28th of March 1802, as Dr. Olbers, a medical practitioner of Bremen, was examining part of the constellation Virgo, he noticed a small star of the seventh magnitude, at a place which he had previously particularly observed, and was confident that he had not seen it there on any former occasion. This being found to be a planet, was designated PALLAS. While resembling Ceres in minuteness, it corresponded also in mean distance from the sun and periodic time, but moved in an orbit of much greater eccentricity, and exceedingly inclined to the plane of the ecliptic. The peculiarities of these bodies led Sir W. Herschel to propose for them the name of *asteroids* (the appearance of stars); and this appellation is still frequently applied to them, as well as to the kindred objects subsequently discovered; but that of *planetoids* is preferable. The fact of two planets being in such close proximity was then altogether unprecedented in the system. This circumstance, together with the minuteness of their volume, and other differences from the ancient planets, led Olbers to surmise that they might possibly be fragments of a large planet which had formerly revolved in the same region, but been shattered by some unknown convulsion. Assuming this startling conjecture to be true, it was reasonably inferred that there were other similar fragments existing; and the quest after them was pursued with zeal and confidence.

The bold hypothesis was apparently sanctioned by a third small planet, discovered on the 1st of September 1804, by M. Harding, an astronomer attached to the observatory of Lilienthal, the place where the scientific congress had been held. It was called JUNO. The

new world coincided with Ceres and Pallas in extreme smallness, and nearly so with their mean distances from the sun; but it surpasses in eccentricity that of any other member of the system, for its orbit is so elliptical that its greatest distance from the sun is nearly double its least.

Another of his supposed fragments, the fourth, was caught by Olbers himself, on the evening of the 28th of March 1807. It received the name of VESTA, and corresponded generally to Ceres, Pallas, and Juno. The planet shines with a more intense light than its compeers, and is not surrounded by any nebulosity. It may therefore be sometimes discovered without a telescope, but a favourable position, a clear evening, and a sharp eye are required. The other planetoids are entirely telescopic objects. Their mean distances and periodic times are as follows:

	Millions of miles.	*Days.*
Vesta	225	1326
Juno	256	1592
Ceres	264	1680
Pallas	267	1686

No addition was made to this number for the space of thirty-eight years. But astronomers were busily engaged in constructing charts of the relative positions of all the stars, down to the tenth order of magnitude, within a zone of the heavens extending thirty degrees in breadth, being fifteen on each side of the celestial equator, to facilitate research. At length, in 1845, discovery took a fresh start; and since that period upwards of fifty members have been added to the group of small planets, all of them having a family likeness and a kindred position. The names of the entire series, down to the year 1859, with the names

of the discoverers, the times and places of discovery, are given in the table.

Planetoids.	*Discoverers.*	*Dates*	*Places.*
1. Ceres	Piazzi	1801, Jan. 1	Palermo.
2. Pallas	Olbers	1802, Mar. 28	Bremen
3. Juno	Harding	1804, Sept. 1	Lilienthal.
4. Vesta	Olbers	1807, Mar. 29	Bremen.
5. Astræa	Hencke	1845, Dec. 8	Driessen, in Prussia.
6. Hebe	Hencke	1847, July 1	" "
7. Iris	Hind	1847, Aug. 13	Regent's Park, London.
8. Flora	Hind	1847, Oct. 18	" "
9. Metis	Graham	1848, April 25	Markree, Ireland.
10. Hygeia	Gasparis	1849, April 12	Naples.
11. Parthenope	Gasparis	1850, May 11	"
12. Victoria	Hind	1850, Sept. 13	Regent's Park, London.
13. Egeria	Gasparis	1850, Nov. 2	Naples.
14. Irene	Hind	1851, May 19	Regent's Park, London.
	Gasparis	" May	Naples.
15. Eunomia	Gasparis	1851, July 29	"
16. Psyche	Gasparis	1852, Mar. 17	"
17. Thetis	Luther	1852, April 17	Bilk, near Dusseldorf.
18. Melpomene	Hind	1852, June 24	Regent's Park, London.
19. Fortuna	Hind	1852, Aug. 22	" "
20. Massilia	Gasparis	1852, Sept. 19	Naples.
	Chacornac	" Sept.	Marseilles
21. Lutetia	Goldschmidt	1852, Nov. 15	Paris.
22. Calliope	Hind	1852, Nov. 16	Regent's Park, London.
23. Thalia	Hind	1852, Dec. 15	" "
24. Themis	Gasparis	1853, April 5	Naples.
25. Phocea	Chacornac	1853, April 6	Marseilles
26. Proserpine	Luther	1853, May 5	Bilk.
27. Euterpe	Hind	1853, Nov. 8	Regent's Park, London.
28. Bellona	Luther	1854, Mar. 1	Bilk.
29. Amphitrite	Marth	1854, Mar. 1	Regent's Park, London
	Pogson	" Mar.	Oxford.
	Chacornac	" Mar.	Paris.
30. Urania	Hind	1854, July 22	Regent's Park, London.
31. Euphrosyne	Ferguson	1854, Sept. 1	Washington.
32. Pomona	Goldschmidt	1854, Oct. 26	Paris.
33. Polyhymnia	Chacornac.	1854, Oct. 28	Paris.
34. Circe	Chacornac	1855, April 6	Paris.
35. Leucothea	Luther	1855, April 19	Bilk.
36 Atalanta	Goldschmidt	1855, Oct. 5	Paris
37 Fides	Luther	1855, Oct. 5	Bilk
38 Leda	Chacornac	1856, Jan. 12	Paris
39 Lætitia	Chacornac	1856, Feb. 8	Paris
40 Harmonia	Goldschmidt	1856, Mar. 31	Paris
41 Daphne	Goldschmidt	1856, May 22	Paris
42 Isis	Pogson	1856, May 23	Oxford
43 Ariadne	Pogson	1857, April 15	Oxford
44 Nysa	Goldschmidt	1857, May 27	Paris
45 Eugenia	Goldschmidt	1857, June 28	Paris
46 Hestia	Pogson	1857, Aug. 16	Oxford
47 Aglaia	Luther	1857, Sept. 15	Bilk
48 Doris	Goldschmidt	1857, Sept. 19	Paris
49 Pales	Goldschmidt	1857, Sept. 19	Paris
50 Virginia	Ferguson	1857, Oct. 4	Washington
51 Nemausa	Laurent	1858, Jan. 22	Nismes
52 Europa	Goldschmidt	1858, Feb. 6	Paris
53 Calypso	Luther	1858, April 8	Bilk

Planetoids.	*Discoverers.*	*Dates.*	*Places.*
54 Alexandra	Goldschmidt	1858, Sept 11	Paris
55 (Not named)	Searle	1858, Sept. 11	Albany, U.S.*

It will be observed that two individuals, Mr. Hind and M. Goldschmidt, discovered a greater number of these bodies than any other observers. They have therefore become familiarly known as the "planet-finders." Mr. Hind was originally attached to the magnetical department of the Royal Observatory, Greenwich. In the year 1844, he accepted the direction of Mr. Bishop's observatory, erected, in 1837, in the grounds of his residence, South Villa, Regent's Park, near the Royal Botanical Society's Gardens. The building is circular, surmounted by a dome, with an arm extended westward as an ante-room, containing various instruments. The circular part, or proper observatory, contains an equatorial telescope, provided with magnifying powers up to 1200, and equipped on the plan known as the English mounting. It was wholly constructed by Dollond, of St. Paul's Churchyard. At this spot Mr. Hind discovered ten of the small planets, and Mr. Marth, an assistant, one. M. Goldschmidt, who has detected eleven, is an historical painter, residing at No. 12 Rue de Seine, Paris.

Nothing is known respecting the magnitude of these bodies, beyond the fact that they are all comparatively minute. The diameter of Pallas has been estimated at not more than eighty miles, while a superficial area about equal to that of the kingdom of Spain has been

* At the time when M. Goldschmidt discovered Daphne, on the 22d of May 1856, the planet had considerably passed opposition, so that only four observations could be obtained before it ceased to be visible. It was hence anticipated that considerable difficulty would be experienced in recognising it upon its coming to opposition in the following year. However, on the 9th of September 1857, Goldschmidt, as he supposed, re-discovered the planet. But it has very recently been ascertained that the object seen by him was in reality not Daphne, but a new planet, which has not yet been named. The detection of this curious fact is due to M. Ernest Schubert. The aggregate number of these small bodies known up to March 1859 amounts therefore to fifty-six.

assigned to Vesta. Dr. Lardner supposes that the average diameter does not exceed a hundred miles. In addition to their small size, the members of the group are distinguished by their orbits being much more elliptical than those of the old planets. They have also a greater inclination, rising and sinking much further from the plane of the earth's path, while their mean distances from the sun closely correspond, and some move in actually intersecting orbits. It has been said, as an illustration of their intimate connexion, "that if the orbits are supposed to be represented materially as hoops, they will hang together in such a manner, that the whole group may be suspended by any given one." Finally, it has been supposed that some of the larger planetoids have irregular and angular surfaces.

The hypothesis respecting the planetoids having been formed by the explosion of a single large planet, originally founded upon their extraordinary conditions, is certainly countenanced by the great number discovered. It has long been considered a very probable opinion. The conjecture has also been added, that some of the smaller fragments, coming within reach of the earth's attraction, occasionally enter our atmosphere, and furnish the *meteors* and *meteorites* which are so inexplicable. But Leverrier has recently called the theory of Olbers in question; and, in place of explaining the existence of the small planets by an alteration in the primitive system of the universe, he believes that they have been regularly formed like all the other planets, and in virtue of the same laws. Whichever opinion may be true, it is certain that fragments of matter visit us from surrounding space; and while some are only seen in fusion in the atmosphere, others are observed to find their way to the surface of the earth. The mysterious phenomenon,

which has excited extraordinary interest in modern times, may therefore be noticed in this place.

METEORS AND METEOR PLANETS.

It is very common, when the curtains of the night are drawn, and clouds are absent from the star-decked sky, or only blot it in patches, for a line of light in the concave to arrest the eye, as though a fiery arrow had been shot from an invisible bow in space, or a star had fallen from its sphere into an extinguishing gulf. Hence the familiar names of shooting and falling stars applied to such apparitions. In certain situations—as when away from the din of towns, on shipboard, in the still valley, or on the solitary moor—the appearance is not a little impressive; and being not more striking than well known in all climes and countries, it has been consecrated in the records of inspiration as an image of the complete and rapid overthrow of principalities and powers. "How art thou fallen from heaven, O Lucifer, son of the morning!" "I beheld Satan as lightning fall from heaven." Often as the sight has been witnessed, it seldom fails to arrest attention, whether contemplated by rustic ignorance or cultivated science, and to fix thought upon the inquiry for the moment, "What can it be?" In the oldest literature we meet with allusions to these swift and evanescent lights. Homer compares the hasty flight of Minerva from the peaks of Olympus, to break the truce between the Greeks and Trojans, to the rapidity of a radiant streamer overhead. Virgil makes it a kind of telegraph between Jupiter and poor old Anchises; and mentions the phenomenon, when frequent, as a prognostic of stormy weather:—

> "And oft, before tempestuous winds arise,
> The seeming stars fall headlong from the skies,
> And, shooting through the darkness, gild the night
> With sweeping glories and long trains of light."

Modern observations show that these and other objects of the same class—the shooting stars, falling stars, fire-balls, and thunderbolts of the vulgar—the meteors, meteorites, aërolites, bolides, eolides, and uranolites of the scientific—are, to a moral certainty, identical in their nature and origin, though differing in their exhibitions. The leading circumstances under which they appear may be stated.

1. Shooting stars, meteors, or whatever else we may call them, vary in their *form*, *magnitude*, and *brightness*. Some consist of phosphoric lines, apparently described by a point; and these are the most numerous class. In others, the globular shape is occasionally very conspicuous, answering to a ball of fire, usually followed by a train of intensely white light; but this is sometimes tinged with various prismatic colours of great beauty. A third variety present no uniform aspect, remain stationary in the heavens, and are visible for a considerable time. Some are not more conspicuous than small stars to the naked eye, while others are more resplendent than the brightest of the planets, and throw a very perceptible illumination upon the path of the traveller.

2. These luminous objects differ likewise in their *height*, *velocity*, and *duration*. A series of observations was carefully conducted by Brandes, with coadjutors, at Breslau and the neighbourhood, between April and October 1823, when, out of a great number, ninety-eight were observed simultaneously at different stations. Of these, at the time of extinction, the computed altitudes were—

4	under	. . . 15	miles.
15	from	15 to 30	,,
22	,,	30 to 45	,,
33	,,	45 ,, 70	,,
13	,,	70 ,, 90	,,
6	above	. . . 90	,,
5	from	140 to 460	,,
98			

The greatest velocity was thirty six miles a second, or double that of the earth in its orbit. But a rate vastly greater has been registered, equal to eleven times that of the earth, and to seven times that of Mercury, the fastest galloper of the planets; and much higher altitudes are on record. Commonly the time of visibility involves only a few seconds. But the luminous trains of the globular class have been seen from several minutes to half an hour after the disappearance of the brilliant balls, while examples of the stationary amorphous kind have remained in sight much longer.

3. Their *direction* is in general more or less oblique, but sometimes it seems horizontal; and the extraordinary fact is mentioned in one instance of a shooting star apparently moving away from the earth, or upwards, as if caught in the act of deserting celestial space, and dragged back into its depths by an attraction superior to terrestrial gravitation. It is usually the case that these objects move from north-east to south-west, which is contrary to the direction of the earth in its orbit.

4. While limited to no particular part of the earth, state of the weather, or season of the year, they are most numerously seen in tropical localities, under

tranquil conditions of the atmosphere, towards the close of summer and the commencement of autumn, especially about the middle of August and of November. The displays have been gorgeous and terrific, as seen in America, when at the same time nothing remarkable has been observed in European skies; while contemporaneously, on other occasions, the revelation has been splendid in the atmosphere of opposite hemispheres. In 1837, a vast number appeared in Europe; and on the same day, on the other side of the globe, they were witnessed from the French ship "Bonite."

5. Commonly the sight is the only sense addressed: "There is no speech nor language—their voice is not heard." But occasionally hissing noises and loud detonations have been distinctly audible, owing, doubtless, to greater nearness. Windows and doors have rattled, and even buildings have trembled at the violence of the explosions. The meteor which passed over Italy in 1676 disappeared to seaward, in the direction of Corsica, with a report which was heard at Leghorn. A similar visitor, witnessed all over England in 1718, passed from north-east to south-west; and the sound of an explosion was heard through Devon and Cornwall, and along the opposite coast of Brittany. This was a very brilliant object. Sir Hans Sloane, being abroad in the streets of London at the time of its appearance—a quarter past eight at night—found his path suddenly and intensely illumined. He at first thought it proceeded from a discharge of rockets; but, looking up, he saw an orb of fire travelling with immense velocity aloft, so vividly bright, that several times he was compelled to turn away his eyes from it. The stars disappeared. The moon—nine days old, and

high near the meridian, the sky being very clear—was so effaced as to be scarcely visible.

6. On the same night the appearance of falling stars is ordinarily limited to two or three examples; and weeks may pass away without a single one being observed. But at times the number is prodigious, as if the whole celestial host had been loosened from the concave to rush in lawless flight towards the earth, resembling a perfect shower of fiery snow. Mediæval chronicles contain records of such events, once considered as marvels invented by the chroniclers, but now admitted to the class of facts, since modern experience is familiar with precisely similar displays. Some of these relations are worthy of notice.

Arabian annalists state, that on the night of the death of King Ibrahim ben Ahmed, referring to the month of October, in the year 902 of our era, an infinite number of falling stars were seen spreading themselves like rain over the heavens from right to left; and this year was afterwards called "the year of stars." In some annals of Cairo it is related, that "in this year (1029 of our era) in the month Redjeb (August) many stars passed, with a great noise and brilliant light." In another place the document states, that in the year 599, on Saturday night, in the last Moharrem (1202 of our era, and on the 19th of October), the stars appeared like waves upon the sky, towards the east and west: they flew about like grasshoppers, and were dispersed from left to right: the people were terror-struck." Mohammed, in a chapter of the Koran, alludes to the falling stars as the visible flame which the angels, guarding the constellations, hurl at the evil spirits who come too near. Hence a modern poet makes his peri fly through space—

"Rapidly as comets run
To th' embraces of the sun;
Fleeter than the starry brands
Flung at night from angel hands,
At those dark and daring sprites
Who would climb the empyreal heights."

On the night of April 25, 1095, both in France and England, the stars were seen "falling like a shower of rain from heaven upon the earth." The Chronicle of Rheims describes them as driven like dust before the wind; and great commotions in Christendom were foreboded in consequence by the members of the council of Clermont. By the common people in England the event was deemed ominous to the king, William Rufus, "that God was not content with his lyvyng; but he was so wilful and proude of minde, that he regarded little their saying."

To come down to modern times, the last century was drawing to a close, when a grand meteoric shower was seen over a very considerable portion of the globe. It became conspicuous towards midnight on the 12th of November 1799, and rapidly waxed terrible, continuing for several hours. To the Moravian missionaries in Greenland, who witnessed the scene, the contrast was of the strangest description—a landscape of unvarying ice and snow around them, and the semblance of the heavens on fire above; for glowing points and masses, thick as hail, filled the firmament, as if some vast magazine of combustible materials had exploded in the far-off depths of space. Humboldt and Bonpland observed the spectacle on the coast of Mexico. The former remarks:—"Thousands of bolides and falling stars succeeded each other during four hours. Their direction was very regular from north to south. From the beginning of the phenomenon there was not a space in the firmament equal in extent

METEORIC SHOWER AS SEEN IN GREENLAND.

to three diameters of the moon which was not filled every instant with them. All the meteors left luminous traces, or phosphorescent bands, behind them, which lasted seven or eight seconds." Mr. Ellicott, at sea off Cape Florida, was another spectator. "I was called up," he states, "about three o'clock in the morning to see the shooting stars, as they are called. The phenomenon was grand and awful. The whole heavens appeared as if illuminated with sky-rockets, which disappeared only with the light of the sun towards daybreak. The meteors, which at any one instant of time appeared as numerous as the stars, flew in all possible directions, except from the earth, towards which they all inclined, more or less; and some of them descended perpendicularly over the vessel we were in, so that I was in constant expectation of their falling on us." The same appearances were seen on the same night by the Capuchin missionary at San Fernando, a village in the llanos of Venezuela; by the Franciscan monks stationed near the cataracts of the Orinoco; at Marca, on the banks of the Rio Negro; at Quito, Cumana, and Santa Fe de Bogota; in French Guiana and Western Brazil; at Nain and Hoffenthal in Labrador; and even at Weimar, Halle, and Carlsruhe in Germany, shooting stars were very numerous. The area of visibility embraced 64° of latitude and 94° of longitude.

Passing by several meteoric showers, more or less remarkable, we come to the most stupendous hitherto witnessed, that of the 13th of November 1833, which, being the third in successive years, all occurring in the same month, and on the same day of the month, seemed to intimate periodicity, and originated the name of the November meteors. The night of the 12th

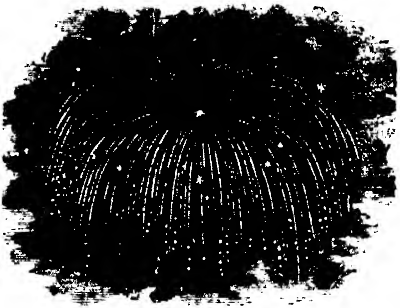
was singularly fine: not a cloud obscured the sky. Towards midnight the spectacle commenced, and was at its height between four and six o'clock in the morning. It was seen all over the United States, from the Canadian lakes to the West Indies, and from about longitude 61° in the Atlantic Ocean to that of 100° in the centre of Mexico. It included the three classes of forms previously mentioned—phosphoric lines, large fire-balls, and luminous bodies of irregular shape. One of the latter, observed in the state of Ohio, resembled a brilliant pruning-hook, apparently about twenty feet long by eighteen inches broad. It was distinctly visible in the north-east more than an hour, and gradually declined towards the horizon till it disappeared. Another, of tabular shape, appeared near the zenith, over the Falls of Niagara, and remained stationary for a considerable time, emitting large streams of light. The roar of the cataract, the wild dash and incessant plunging of the waters below, with the fiery storm overhead, combined to form a scene of unequalled sublimity. Some persons died of fright. Many thought that the last great day had come.

In the slave states the terror of the negroes was extreme. "I was suddenly awakened," says a planter in South Carolina, "by the most distressing cries that ever fell on my ears. Shricks of horror and cries for mercy I could hear from most of the negroes of three plantations, amounting to from six to eight hundred. While earnestly listening for the cause, I heard a faint voice near the door calling my name. I arose, and, taking my sword, stood at the door. At this moment I heard the same voice still beseeching me to rise, and saying, 'Oh! master, the world is on fire.' I then opened the door, and it is difficult to say which excited

me most, the awfulness of the scene, or the distressing shrieks of the negroes. Upwards of one hundred lay prostrate on the ground, some speechless, and some with the bitterest cries, but most with their hands raised, imploring God to save the world and them. The scene was truly awful; for never did rain fall much thicker than the meteors fell towards the earth. East, west, north, and south, it was the same." An observer at Boston compared them, when at the maximum, to half the number of flakes seen in the air during an ordinary snow-storm. When they became less dense, so as to admit of being individualized, he counted 650 in fifteen minutes, in a vertical zone which did not include a tenth part of the visible horizon; and this number, in his opinion, was not more than two-thirds of the whole. Thus there would be 866 in his circumscribed zone, which gives 8660 for the entire hemisphere every quarter of an hour, or 34,640 per hour; and as the phenomenon continued seven hours, the grand total of falling stars and meteors visible at Boston on this memorable night exceeded 240,000. The spectacle must have been of the sublimest order. The apostle John might have had it before him when he indited the passage referring to the opening of the sixth seal:—"And the stars of heaven fell unto the earth, even as a fig-tree casteth her untimely figs, when she is shaken of a mighty wind."

Some leading conclusions relative to this magnificent display, deduced by scientific eye-witnesses, chiefly Professor Olmstead, may now be concisely stated. *First:* The meteors had their origin beyond the limits of our atmosphere. They all, without a single exception, moved in lines which converged in one and the same point in the heavens, as indicated by the diagram.

But this course commenced at different distances from it, while around the point itself there was a circular



space of several degrees in which none appeared. The position of this radiating point with reference to the stars was near γ in the constellation Leo. It was stationary among the stars during the whole period of observation; or, in other words, instead of accompanying the earth in its diurnal rotation, it attended the stars in their apparent movement westward. Thus the common focus from which the meteors seemed to emanate was clearly in the regions of space exterior to our atmosphere. *Secondly:* The height of the place whence they proceeded, though not accurately determined, must have been several thousand miles above the surface of the earth. This was inferred from observations of parallax. *Thirdly:* The meteors did not fall by the force of gravity alone, for the velocity observed was estimated to be much greater than could possibly result from the law of gravitation.

Fourthly: They consisted of combustible matter, took fire, and were consumed in traversing the atmosphere. They were not luminous in their original situation in space, otherwise the body would have been seen from which they emanated. Combustion ensued upon reaching the atmosphere, owing to the heat evolved by the sudden and powerful compression of the air consequent on their tremendous velocity; and the combustion was complete, since no particles, notwithstanding the momentum, made their way to the surface of the earth. *Fifthly:* Some of the meteors were evidently bodies of considerable size. Several fire-balls were observed, apparently as large as the full moon. Dr. Smith, of North Carolina, who was travelling all night on professional business, thus describes one:—"In size it appeared somewhat larger than the full moon rising. I was startled by the splendid light in which the surrounding scene was exhibited, rendering even small objects quite visible; but I heard no noise, although every sense seemed to be suddenly aroused, in sympathy with the violent impression on the sight." *Sixthly:* The large meteors were still high in the atmosphere when they exploded, or resolved themselves into smoke, for evidently the same objects were observed from far distant points; and while the explosions were seen, no report of any kind reached the ear.

While the eye was alone appealed to upon this occasion, the ear, as before remarked, has been addressed, and the sense of touch has taken cognizance of kindred phenomena.

The fall of masses of solid matter from the higher regions of the atmosphere, sufficiently heavy to plough up the surface of the ground, sink deep into the soil, and cleave the trunk of the oak if in their way, is as much a

verity of terrestrial history, as the dropping of the small rain upon the tender herb, the descent of the feathery snow and rattling hail. It is true that this wonderful and profoundly mysterious phenomenon has not obtained a place in the catalogue of dangers to which life and limb are exposed. But though of rare occurrence, it must be remembered, that while scarcely a year elapses without a recorded example, probably the known instances bear a very small proportion to the actual number, owing to circumstances hiding them from observation. In the wide range of the ocean there is scope enough utterly solitary, for nature, without eye-witnesses, to act the part of the mighty angel in the Apocalypse, and take "a stone like a great millstone, and cast it into the sea." The same remark applies to the vast unoccupied lands of the globe, its mountains, forests, and deserts; and obviously in countries upon which the human race are thickly planted, many may escape notice by descending in the night. All antiquity, from the earliest times, was filled with rumours respecting heaven-fallen bodies. Priestly and political craft took advantage of the popular impression, and attached the idea to particular objects, in order to create and strengthen a veneration for them. Hence the celestial origin ascribed to the palladium of Troy, the sacred shield of Numa, and the object of Ephesian idolatry. "What man is there that knoweth not how that the city of the Ephesians is a worshipper of the great goddess Diana, and of the image which fell down from Jupiter?"*

The accounts current respecting these droppings from the sky were long treated by philosophy as idle tales. But all scepticism as to the transition of sub-

* Acts xix. 35.

stances from celestial space to the terrestrial surface has been completely abandoned. The evidence of the reality of such remarkable deposits is incontestible; and in some instances, philosophers themselves have been eye-witnesses of the descent. The term *aërolites* is commonly applied to the strange wanderers, signifying atmospheric stones. They are also called *meteoric iron*, when almost entirely metallic in their composition; and *meteoric stones*, when in connexion with metals the proportion of other minerals is considerable. They appear to have been styled "sun-stones" and "moon-stones" by the vulgar, from their presumed solar or lunar origin, according as they were observed to fall in bright sunshine, or descended at night. A mass fell at Ensisheim, in Alsace, in 1472, when the emperor Maximilian was there with his army, which weighed 260lbs. The fall of another, of 59lbs., was observed by Gassendi in the neighbourhood of Nice, in 1627. A fire-ball was seen in 1790, in the south of France; and, after a loud explosion, a shower of stones descended over a considerable extent of ground, of different sizes, and at different distances. In 1795, on the afternoon of a serene day, an explosion in the air was heard near Wold Cottage, in Yorkshire; and an aërolite was seen to strike the earth which weighed 56lbs. In 1803, a fiery globe of great brilliance was beheld traversing the atmosphere with immense rapidity over great part of Normandy; loud reports were heard, like the discharges of artillery; and a multitude of mineral masses were precipitated to the ground. Three thousand were picked up, the largest of which weighed 17½lbs. A commission of inquiry, appointed by the Academy of Sciences, examined all the circumstances of the event, at the head of which was the

celebrated M. Biot. A great number of other examples might be cited, occurring in different parts of the world, Europe, India, the Cape, and America. The visitor to the British Museum may see specimens of these gifts from surrounding space in the cabinets of its mineralogical department, some of which are described on the labels as follows:—

"Two fragments of the Tipperary meteorite which fell in August 1810: it contains quartz globules of a green colour, owing to oxides of nickel.

"A fragment from one of those of Berlanguillas, in Catalonia, July 8th, 1811.

"A fragment of one weighing 66 pounds, which fell August 5th, 1812, near Chantonnay, between Nantes and La Rochelle, Department of the Vendée.

"Fragment of the meteoric stone which fell at Adare, in the county of Limerick, Ireland, September 10th, 1813.

"Fragment of the stone which fell in March 1814, in the vicinity of Wiborg, in Russian Finland.

"Fragment of one which fell Sept. 5th, 1814, at Agen, in the Pyrennees.

"A portion of the meteorite of Chassigny, near Langres, Dep. of the Upper Marne, which fell on the 3rd of October 1815.

"Fragment of the largest of those that fell at Juvénas, Dep. of the Ardêche, 15th of June 1821.

"A portion of the meteorite which descended at Nanjenoy, in Maryland, February 10th, 1825.

"Fragment of one of the meteorites which fell May 9th, 1827, at Drake's Creek, Nashville, Tennessee.

"Loose grains of that of Chesterfield, Virginia, June 4th, 1828.

"A meteorite, weighing about four pounds, which

fell at the village of Akburpoor, in the district of Saharanpore, April the 18th, 1838.

"A fragment detached from one of the three stones which, on June the 6th, 1838, simultaneously fell at three villages, about a mile distant from each other, in the valley of Berar, in the East Indies.

"Two of those that were seen to fall, October 13th of the same year, at Old Bokkeveld, at the Cape of Good Hope, the larger presented by Sir John Herschel."

If examined immediately after their descent, aërolites have invariably a temperature more or less elevated. It is also a striking circumstance, ascertained from the manner in which they penetrate the soil, that they do not fall in a right line, but strike the earth in a very oblique direction. Chemical analysis discloses no ingredient in their composition foreign to the materials of our own globe: but not more than twenty out of the sixty chemical elements, or simple substances, that enter into the constitution of the earth, have ever been discovered in meteoric bodies. No individual example contains this number; and in every case the materials are combined in a manner altogether new, and unlike any thing known in terrestrial mineralogy. Non-metallic substances occur in much larger quantities in the crust of the earth than the metallic; but the reverse is the case with reference to aërolites. Many are masses of nearly pure metal, chiefly iron, with a small proportion of nickel. Others contain cobalt, manganese, chromium, copper, and other metals, diffused through them in minute quantities, with a small per centage of oxygen, sulphur, and chlorine. The stony meteorites consist chiefly of silica and metallic oxides.

In explanation of the facts stated, four hypotheses

have been entertained, the Terrestrial-Volcanic, the Lunar-Volcanic, the Atmospheric, and the Planetary.

According to the first hypothesis, aërolites were supposed to be projectiles from the terrestrial volcanoes. But this idea has long been abandoned, because they fall on parts of the earth thousands of miles apart from the nearest volcano, while coincident volcanic eruptions have not been observed, and the meteoric masses have no analogy to volcanic products.

The second hypothesis, that the masses derive their origin from lunar volcanoes, was once extensively received by men of science. It was calculated by Laplace and others, that a body projected from the moon with an initial velocity of 8000 feet a second, would not fall again to it, but pass into the sphere of the earth's attraction, and either circulate round it as a satellite, or descend to the terrestrial surface. But various circumstances concur to show the extreme improbability of the moon being at present the scene of volcanic activity, while the orb must, ere this, have been visibly wasted by the projection of such an enormous number of bodies as have glowed in our atmosphere, constituting the shooting stars of all ages, and the meteoric showers, in addition to the actually deposited masses. This theory has, therefore, been entirely set aside.

The next supposition, that, like rain and hail, these remarkable objects are formed by aggregation in the atmosphere of materials carried up from the surface of the earth in excessively minute particles, though apparently simple and natural, is still more inadmissible. Rain and hail are formed in the air, because it is charged with aqueous vapour, which a sufficiently low temperature can reduce to a liquid and a solid state. But no analysis of the air, made from the level

of the sea to very great elevations, has ever yielded any of the constituents of meteoric stones—neither iron. nor nickel, nor manganese, nor silex, nor sulphur, nor gases capable of holding in solution earthy or metallic substances. Even supposing, as Arago remarks, the constituents really existed in the atmosphere, and were not to be detected on account of their minute subdivision, it would still be necessary to explain, with such feeble and dispersed elements, a sudden precipitation, yielding stones of several hundred weight, as the one at Ensisheim; or three thousand stones, of various sizes, like those which were separated and shot off by the Normandy meteor. The elements that form hail are incomparably more abundant in the air than those of aërolites can be supposed to be; yet hailstones of several hundred weight have never been seen. In addition, rain and hail obey the laws of gravitation in their descent. They not only meet the earth with a velocity due to the height from which they fall, but strike it in a right line, or without any other deviation from it than that which is occasioned by the winds. But the observed velocity of meteorites is far greater than what can possibly be the result of terrestrial gravity; and the direction in which they strike the earth is always more or less oblique. The atmospheric hypothesis must therefore be rejected.

The remaining theory, the Planetary, is now generally accepted as the true solution of the problem. It is probable, that as the planetoids are vastly smaller than the old planets, while numerically superior, so bodies vastly inferior to these small orbs may exist in the system, circulating round the sun, subject to great perturbations, which, being closely approached by the earth in its orbit, are drawn towards it by the force of

the terrestrial attraction. These "starlets," "bits of stars," and "meteor planets," as they have been called, are not visible in a normal condition, because of their minuteness. But on entering our atmosphere, they are rendered luminous, owing to the heat evolved by the sudden and violent compression of the air in front of the moving body. According to this view, shooting stars, which simply dart athwart the heavens, may be regarded as coming within the limits of the atmosphere, and carried out of it again by their immense velocity, passing on in space. Meteoric showers may result from an encounter with a great group of these bodies, while aërolites are those which come so far within the sphere of the earth's attraction as to be precipitated to the surface, "as weary and forlorn birds of passage, far out at sea, are entangled in the rigging of vessels, and fall helpless on deck." These are not established conclusions, but invested with a high degree of probability.

CHAPTER IX.

JUPITER AND HIS SATELLITES.

Zone of Separation in the System—Outer Group of Planets—Their Characteristics—Greater Magnitude and Less Density—Longer Years and Shorter Days—Jupiter—Discovery of the Belts—Probable Explanation—Satellites of Jupiter—Galileo's First Observations—Magnitude and Distances of the Satellites—Results of their Discovery—Confirmed the Copernican System—Kepler, Sizzi, Galileo—Satellites seen by the Naked Eye—Determination of Terrestrial Longitudes—Eclipses of the Satellites—Number and Duration—Singular Observation of Admiral Smyth—Jupiter deserted by his Guards—Progressive Motion of Light—Discovery of Roemer—Velocity of Light.

The region of the minor planets may be regarded as a zone of separation dividing the larger ones into two groups, an inner and an outer, in many respects differing from each other. The Earth belongs to the inner group, with Mercury, Venus, and Mars, which may be called terrestrial planets, owing to their comparative proximity to us, and many analogies to our globe. The outer group consists, likewise, of four members, Jupiter, Saturn, Uranus, and Neptune, bodies remarkably distinguished from the former by their vast magnitude. Thus the volume of Jupiter exceeds by 1330 times that of the earth, while the three others are in order, 857, 88, and 107 times larger than our world. If a pea be taken to represent the bulk of the earth, a moderate-sized orange will proportionably show the dimensions of Jupiter, a small orange will serve to display those of Saturn, a full-sized cherry those of Uranus, and a plum those of Neptune. But while of far superior magnitude, the

greater planets are composed of much lighter material than the lesser. The density of the Earth, Venus, and Mars is nearly the same, amounting to about five and a half times that of water. Balls of iron-stone of equal size, placed in colossal scales against them, would keep the balance even, while a corresponding ball of gold would do the same for Mercury. But to effect a similar equipoise, in the instance of Jupiter, it would only be necessary to have a globe of hard wood, as ebony or lignum vitæ, of the same dimensions, one of a lighter kind of wood for Uranus and Neptune, and one still lighter, as deal, or cork nearly, for Saturn. Thrown into an ocean capacious enough to receive them, the lesser planets would sink as lead in the waters, while the greater would descend slowly, or float heavily, or be distinctly buoyant. Jupiter, Saturn, Uranus, and Neptune, though respectively 1330, 857, 88, and 107 times larger than the earth, are only 338, 101, 14, and 19 times heavier.

The planets of the outer group are likewise distinguished from those of the inner by the great length of their periods of revolution, immense rapidity of rotation, and the vastness of the interplanetary spaces. Thus the period of Jupiter's revolution round the sun, or his year, includes nearly twelve of our years, while the periods of Saturn, Uranus, and Neptune, embrace respectively 29½, 84, and 164 terrestrial years. But with such tremendous velocity do these planets whirl round upon their axes, that Jupiter and Saturn, notwithstanding their greater comparative magnitude, make more than two rotations while the earth makes one. Light and darkness, day and night, complete an alternation at their surfaces in about every ten hours. The relative distances of these bodies from

each other, and from the sun, strikingly distinguish them from those of the inner group. All the latter revolve within 145 millions of miles of the solar globe, the mean distance of Mars; but the distances of the former are respectively, Jupiter 494, Saturn 900, Uranus 1800, and Neptune 2800 millions of miles from the central luminary. These mighty spaces, with the consequent reduction in the apparent magnitude of the sun, as seen athwart them, are best appreciated by being pictorially represented. It is not at all improbable, that the apparently inexplicable rapid rotation of the remote planets may be an arrangement whereby processes are carried on conducive to the generation of light and heat by the solar rays, compensating for the effect of remoteness.

Jupiter, the largest planet of the system, is also the brightest, with the exception of Venus, whom, however, he sometimes rivals, and even surpasses in brilliance. His mean distance from the sun, 494 millions of miles, is more than five times that of the earth; his diameter, 88,640 miles, is equal to eleven times that of our globe; his orbital revolution, performed in 4332 terrestrial days, extends through nearly twelve years; and yet in rather less than ten hours the enormous ball turns upon its axis, with a velocity at the equator 27 times greater than that of the corresponding portion of our planet. This swift motion renders the form of Jupiter spheroidal, like that of the earth from a similar cause, but to a much more considerable extent. It must occasion also rapid changes of sky. The sun by day, and the stars by night, will appear passing with great celerity across the celestial vault. Owing to the axis of the planet being nearly perpendicular to the plane of the orbit, the days and nights are always

nearly equal, so that no important change of seasons can be experienced. It is not to be understood that one uniform season prevails from the equator to the poles; but that the same parallels of latitude uniformly enjoy the same season, whatever it may be. The vast size of this glorious orb may be conceived on recollecting that a line carried out from the earth to the moon would not girdle it at the equator.

Seen through a good telescope, Jupiter presents one of the most interesting and splendid spectacles in the heavens. The disk expands into a large bright orb; the spheroidal figure, consequent on the great velocity of rotation, is palpably exhibited; obscure parallel stripes, or belts, appear encompassing the body; and four radiant satellites, always in attendance, and ever varying their positions, compose a stately retinue. The horizontal stripes, or belts, which appear extending across the surface of the planet, are not permanent phenomena, but vary in number, magnitude, and mutual distance. They escaped the observation of Galileo, his instrument not being sufficiently powerful to exhibit them; and were first seen by Zucchi, an Italian Jesuit, at Naples, on the 17th May, 1630, when two were noticed. Fontana, in 1633, saw three belts; but Grimaldi, in 1648, could only perceive two. Four dark belts and two white ones were observed by Campani, in 1664. As many as eight-have been distinctly recognised; and the whole surface of the planet has occasionally been seen covered with them. In general, three are to be distinguished; sometimes only one; but this is always the principal belt, situated on the northern side of the planet's equator. Besides these bands, irregular dusky spots diversify the rest of the surface; and both belts and spots undergo very rapid

transformations, indicating the existence of an atmosphere and violent atmospheric commotions. In addition, there are spots of a more permanent character, which vanish, but re-appear in precisely the same position, and with the same aspect, as if adhering to the body of the planet. It is supposed, that currents analogous to our own trade-winds, which blow generally in the direction of the equator, and depend upon the earth's rotation, are originated upon a grand scale, by the velocity with which Jupiter rotates. By these currents, clouds and vapours floating in the atmosphere, which reflect more light than the body of the planet, are thrown into parallel strata, forming luminous zones, between which the opaque body of the great orb appears, constituting the dusky belts. The fluctuating spots may be the effect of dense and transient heaps of clouds; and the permanent ones may be parts of the planet's surface, hidden and revealed by the atmospheric changes.

The four satellites revolving round the stupendous planet are readily discerned with an instrument of moderate magnifying power; but of their existence the world had not the slightest conception till Galileo made the discovery. This was one of the first fruits of the telescope. The first James was then on the throne of England, and the fourth Henry on that of France. On the night of the 7th of January 1610, three small but very bright stars were observed in the neighbourhood of Jupiter, ranged in a straight line, two on the east and one on the west side of him. They were imagined to be three telescopic fixed stars, yet were much brighter than such objects of the same magnitude, and there was something in their appearance which powerfully arrested attention. Inspecting the

planet again on the following night, the 8th, Galileo was surprised to find a different arrangement of the stars, for they were all now on the west side, and nearer each other than on the previous evening. This change excited astonishment, and the next night was waited for with great impatience, but clouds mantled the sky, forbidding observation. On the 10th, only two of the stars were seen, and they were both on the east side of Jupiter, upon which the suspicion arose, that the third might be concealed behind the body of the planet. On the 11th, the observation was renewed, and two stars were again seen, but one of them was nearly twice as large as the other. By this time all doubt had been removed from the mind of the observer as to the real character of the objects. On the 12th, the lost star began to appear about three o'clock in the morning, emerging from the eastern side of the planet; on the 13th, four stars were finally seen; and future observations speedily established the fact of four satellites revolving round Jupiter in the same manner as the planets revolve around the sun.

As usual at that time in such cases, there were several claimants for the distinction of having first caught sight of these hitherto unknown bodies. Simon Mayer was a candidate for the honour; and while Galileo named his prizes the Medicean stars, in compliment to his patron, Cosmo de' Medici, the Grand Duke of Tuscany, his competitor proposed the mythological names of Io, Europa, Ganymede, and Callisto. But Mayer's claim to priority being unfounded, his nomenclature was rejected, lest its use should lend a sanction to his pretensions; and the denomination of the discoverer has not been retained, as it seems to be a kind of astronomical law with nations, not to allow

the names of real personages, discoverers or patrons, to be transferred to the skies, in order to avoid jealousy.* The satellites are therefore simply distinguished, and that without confusion, as the first. second, third, and fourth, in order of distance from the primary. The *third* is the largest, and exceeds the planet Mercury by a small quantity; the *fourth* is the second in magnitude; the *first* is the third in magnitude; and the *second* is the smallest, being about the size of our own

Sat.	Diam. in Miles.	Dist. from Jupiter.	Time of Revolution.
1	2,429	260,000	1d. 18h. 28m.
2	2,180	420,000	3 13 14
3	3,560	670.000	7 3 43
4	3,046	1,180 000	16 16 32

Rapidity of motion, with magnificent dimensions, is characteristic of the system of Jupiter. We have remarked the immense velocity with which the planet rotates upon its axis; and in forty-two hours the first satellite flies round the stupendous globe. This period, equal to four Jovian days, constitutes its month; and in this brief interval the satellite is a crescent, a semi-circle, gibbous, full, and eclipsed, as seen from the primary. The laws of the planetary motions, as ascertained by Kepler, are strictly fulfilled in the system of Jupiter; and it may therefore be regarded as an exquisite miniature likeness of the great solar system. The interesting fact has also been ascertained, that, like our own moon, each of the four satellites performs a complete rotation on its axis in a period equal to that

* So much was this honour coveted, that Galileo was expressly applied to by the court of France, with a view to the satellites being named after the reigning monarch, Henry IV. A plain intimation was given, that by compliance he would render himself and family rich and powerful for

of its revolution round the planet; and probably all the secondary bodies in the system are subject to this law.

The discovery of Jupiter's satellites was not simply an event of interest in itself, but one upon which important results were grafted, some of which may be stated.

1. It contributed to convict the world of intellectual error, and establish the *Copernican system of astronomy*. A false, because an uninductive philosophy, judging according to the outward appearance, and not venturing to look beyond it, had taught for ages the doctrine, that the earth must be the central point of the celestial motions. The fact of a satellite being in attendance upon it was deemed a proof of its pre-eminence, no similar distinction having been observed in relation to any luminary in the heavens. In ignorance and pride, the terrestrials had been saying, in thought if not in word, "We occupy the most dignified body in the creation; we are alone provided with a companion orb, plainly in intimate connexion with our world, and subsidiary to it; hence the attitude and the post of superiority are the earth's indefeasible rights; we repose at the centre of the scheme of nature." These high imaginations were at once cast down when the true constitution of Jupiter and his moons was known.

Still, to the majority of men, it is distasteful work to abandon notions that have grown with their growth, and strengthened with their strength; and besides its being mortifying to intellectual vanity to be convicted of error, they disrelish the mental disturbance occasioned by the breaking up of old associations in their ideas, and the toil which a correct conception of truth may

require. Hence, because the existence of these secondaries of the planet contradicted long established opinions, numbers stoutly persisted in contesting the fact of their having been observed, though so easily capable of being decided by a direct appeal to the eye. Some maintained that the telescope represented terrestrial objects correctly, but was not to be relied on for the heavens. A professor of Padua refused to look through the instrument, lest he should be constrained to acknowledge what he did not wish to admit. "Oh! my dear Kepler," wrote Galileo, "how I wish that we could have one hearty laugh together! Here, at Padua, is the principal professor of philosophy, whom I have repeatedly and earnestly requested to look at the moon and planets through my glass, which he pertinaciously refuses to do. Why are you not here? What shouts of laughter we should have at this glorious folly!" Martin Horky, one of Kepler's scholars, but a total stranger to the candour of his master, signalized his prejudices by the remark, "I will never concede his four new planets to that Italian, though I die for it." His punishment was severe, yet appropriate. Having fallen under the displeasure of Kepler, and being anxious to be reconciled, he was pardoned, but only upon consenting to look through a telescope, and confess that he saw Jupiter's moons.

As this discovery raised the number of bodies then known in the system from seven to eleven, Sizzi, an astronomer of some note, undertook to disprove it by the following logic: "There are seven windows given to animals in the domicile of the head, through which the air is admitted to the tabernacle of the body, to enlighten, to warm, and to nourish it; which windows are the principal parts of the microcosm, or little

world, two nostrils, two eyes, two ears, and one mouth. So in the heavens, as in a macrocosm, or great world, there are two favourable stars, Jupiter and Venus; two unpropitious, Mars and Saturn; two luminaries, the sun and moon; and Mercury alone undecided and indifferent. From which, and from many other phenomena of nature, such as the seven metals, etc., which it were tedious to enumerate, we gather that the number of planets is necessarily seven. Moreover, the satellites are invisible to the naked eye, and therefore can exercise no influence over the earth, and therefore would be useless, and therefore do not exist. Besides, as well the Jews and other ancient nations, as modern Europeans, have adopted the division of the week into seven days, and have named them from the seven planets. Now, if we increase the number of planets, this whole system falls to the ground."

So clamorous and confident were the objectors, that Kepler wrote to Galileo, to furnish him with arguments by which to answer them. The latter replied: "In the first place, I return you my thanks that you first, and almost alone, before the question had been sifted, (such is your candour and the loftiness of your mind,) put faith in my assertions. You tell me you have some telescopes, but not sufficiently good to magnify distant objects, and that you anxiously expect a sight of mine, which magnifies images more than a thousand times. It is mine no longer, for the Grand Duke of Tuscany has asked it of me, and intends to lay it up in his museum, among his most rare and precious curiosities, in eternal remembrance of the invention. You ask, my dear Kepler, for other testimonies. I produce for one the Grand Duke, who, after observing the Medicean planets several times with me at Pisa,

during the last month, made me a present at parting, of more than a thousand florins, and has now invited me to attach myself to him, with the annual salary of a thousand florins, and with the title of 'Philosopher and Principal Mathematician to his Highness,' without the duties of any office to perform, but with the most complete leisure. I produce for another witness, myself."

It has been asserted, that in certain parts of the globe, where the air is pure and the climate fine, the satellites may be discerned without a telescope. Etna, the Apennines, and the West Indies, have been mentioned as sites where the feat is practicable to a good eye, and has been actually performed. Observers on the top of Etna, and other great heights, have often been struck with the unwonted splendour of the nocturnal heavens, for the number of visible stars is increased by the elevation, and the light of each appears brighter than usual, while the starless spaces are intensely black. "The whiteness of the Milky Way," says Brydone, "was like a pure flame that shot across the heavens, and with the naked eye we could observe clusters of stars that were invisible in the regions below. We did not at first attend to the cause, nor recollect that we had now passed through ten or twelve thousand feet of gross vapour, that blunts and confuses every ray before it reaches the surface of the earth. We were amazed at the distinctness of vision, and exclaimed together, 'What a glorious situation for an observatory! Had Empedocles had the eyes of Galileo, what discoveries must he not have made!' We regretted that Jupiter was not visible, as I am persuaded we might have discovered some of the satellites with the naked eye."

But Admiral Smyth, a gazer in some of the clearest skies in the world, carefully tested this point on the summit of Etna with an eye of average power; and came to the conclusion, that while the planet was most brilliantly conspicuous, his moons are not perceptible to the unassisted vision, from their fainter light, or they must otherwise have been detected by observers among the ancients. Nevertheless, there are not wanting testimonies of an opposite tenor, made by respectable parties; and it cannot be disputed, that many persons have visual organs of extraordinary power. Baron Zach relates, that the late Père Hell told him, that he had known an officer of the Hungarian guard at Vienna, who could see the satellites without optical aid, as was proved by simultaneous observation with the telescope. M. Mädler mentions the remarkable case of the postmaster, Nernst, who thus saw *one* satellite, and drew a diagram of its position. But when the telescope was applied, it was found that three satellites had nearly closed, or were arranged nearly in a line with each other, and their united brightness caught the piercing eye of the observer. "I never," says Sir John Herschel, "saw Jupiter's satellites with my naked eye at all, and I regard all accounts of their having been so seen as in some degree apocryphal. Dr. Wollaston, who had a keen eye, told me he had never succeeded, though he cut off the light of the planet by hiding the body behind a distant object."

2. Another immediate consequence of the discovery of these bodies was their use in the *determination of terrestrial longitudes.* They furnished a much more accurate method than had been known before for solving a problem of the greatest practical importance to the interests of mankind. Eclipses of the satellites,

perfectly analogous to those of our own moon, very frequently occur, all of them, except the fourth, passing through the shadow of Jupiter in every revolution. This arises from their orbits being very little inclined to that of their primary. As the periodic time of the most interior satellite is under two days, it undergoes in that interval a total eclipse. Nothing can be simpler in principle than the method of finding the longitude by observation of the event. The times of immersion and emersion, or the passing of the satellites into and out of the shadow of the planet, are calculated in advance for the meridian of Greenwich, and published in the Nautical Almanac. An observer at any other place has only to note when the immersion or emersion does actually happen where he is; and the difference between the time at his station and that recorded in the almanac gives him his longitude, east or west of Greenwich, according as the observed time is greater or less than the computed.

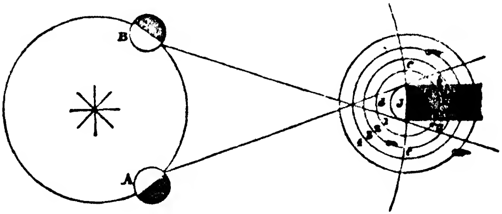
But though simple in principle and easy to practise at a fixed observatory, such as a landsman may command, the method is not susceptible of yielding a very exact result, and more certain modes for finding the longitude are now known. Owing to the phenomenon being gradual and not instantaneous, it is difficult to determine precisely the moment of immersion or emersion, much depending upon the goodness of telescopes, the eyes of the observer, and the state of the atmosphere at his station. To the mariner, also, observation is very often altogether impracticable, from the oscillations of his vessel. Still the eclipses of Jupiter's satellites for some time supplied mankind with the most accurate means for determining a vitally important question; and as useful natural signals at present for the purpose, their

elements for Greenwich are regularly calculated beforehand at the national observatory, for the benefit of the maritime world. It has been stated by a competent authority, Admiral Smyth, as the result of his own practice, that these phenomena may be fairly observed at sea in tolerably fine weather, and the longitude obtained within seventeen or eighteen miles. It is not more marvellous in itself, than a proof of beneficent design in the construction of the universe, that a ship freighted with emigrants from Ireland, or cotton from New York, in the midst of the Atlantic,

> "Alone, alone, all, all alone,
> Alone on the wide wide sea,"

may be usefully aided in having its position indicated by a body passing into or out of a shadow projected into space hundreds of millions of miles away from us.

It is never the case that both the immersion and emersion can be observed in the instance of the first satellite, and rarely in that of the second, though it is otherwise with the third and fourth, in consequence of their



greater relative distance from the planet. Let A B represent the earth in different parts of its orbit; and J Jupiter, surrounded by his moons, whose orbits are

marked 1 2 3 4. The first satellite is shown entering the planet's shadow at *a*, while *b* is the point of emergence from it. A spectator on the surface of the earth at A will see the immersion, but not the emersion, owing to the interposing body of the planet; and for the same reason, when the earth is at B, the immersion will not be visible, but the emergence will be seen. The eclipses of the four satellites last on an average respectively about $2\frac{1}{4}$, $2\frac{3}{4}$, $3\frac{1}{2}$, and $4\frac{1}{2}$ hours. They occur about eighteen times every month in the case of the first satellite; eight or nine times in that of the second; four times in that of the third: but the fourth frequently escapes the shadow of the central body, owing to the inclination of its orbit, and suffers only a few eclipses in the year. The inhabitants of the grand orb, if there are such, witness four thousand five hundred eclipses of their moons in the course of the Jovian year.

Galileo was the first to appreciate the use of these bodies in deciding the longitude of places on the earth; and diligently were they observed for the purpose of ascertaining the time occupied by each in its revolution round the planet. Obliged by blindness to desist, he resigned the prosecution of the task to his pupil and friend Vicenzo Reineri, a Genoese monk. While the latter lay upon his death-bed, the papers containing the result of their joint labours were stolen from his cell, and remained unknown till April 1843, when they were found by Signor Alberi, in the library of the Palazzo Pitti, at Florence. A manuscript notice exists in the library at Carpentras, near Avignon, of an eclipse of a satellite having been observed by J. Lombard at Malta, so early as the year 1612; but owing to the imperfection of instruments, upwards of half a

century elapsed before regular and systematic scrutiny commenced. James Gregory, the inventor of the reflecting telescope which bears his name, may almost be said to have fallen a victim to this object, for while intent upon Jupiter's moons with his instrument, in October 1675, he was struck suddenly with total blindness, and died a few days afterwards, at an early age.

The satellites disappear with reference to a terrestrial spectator, by passing behind the body of the planet, without being in the shadow, and are then said to be occulted. They also interpose in a direct line between Jupiter and the earth, accomplish transits across his disk and occasion eclipses of the sun to those regions of the primary upon which their shadows are projected. It is seldom the case that they can be seen when on the body of the planet, except powerful telescopes are used; but the phenomenon of apparent contact may be readily observed. A singular incident came under the notice of Admiral Smyth, at Bedford, which he thus communicated to the Royal Astronomical Society: "On Thursday, the 26th of June 1828, the moon being nearly full, and the evening extremely fine, I was watching the second satellite of Jupiter as it gradually approached to transit its disk. My instrument was an excellent refractor of 3¾ inches aperture, and five feet focal length, with a power of 100. It appeared in contact at half-past ten, by inference, and for some minutes remained on the edge of the limb, presenting an appearance not unlike that of the lunar mountains coming into view during the first quarter of the moon, until it finally disappeared on the body of the planet. At least twelve or thirteen minutes elapsed, when, accidentally turning to Jupiter again, to my

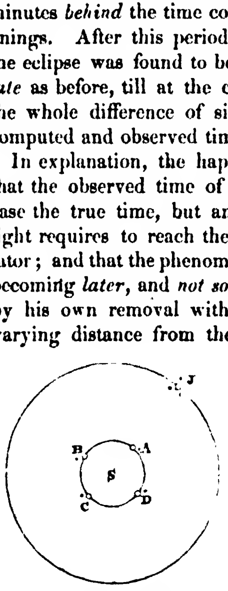
astonishment I perceived the same satellite *outside the disk.* It was in the same position as to being above a line with the apparent lower belt, when it remained distinctly visible for at least four minutes, and then suddenly vanished." The same appearance was noticed by Mr. Maclear of Biggleswade, and Dr. Pearson of South Kilworth, three observers at distant stations, with telescopes of different apertures, all positive as to the extraordinary deviation from rule. It could not, therefore, be an error of observation, or an illusion of vision, but was probably caused by some real, though transient, change in the deflection of light, of a purely incidental nature.

One instance is on record of Jupiter appearing deserted by his guards, all the satellites being behind the body of the planet, or immersed in his shadow. This was witnessed by Molyneaux, November 2, 1681. Such a spectacle has never been seen since; and supposing present arrangements to be maintained, the conjunction cannot occur again under an interval of ages which completely baffles our conceptions.

3. There is another obligation which we owe to these attendants of Jupiter, and not the least important, the discovery by their means of *the progressive motion and appreciable velocity of light*, which had before been considered instantaneous in its transmission. This was the achievement of the eminent Danish astronomer Olaus Roemer, in the year 1674; and he was led to it by observation of the eclipses of the satellites. Wishing to determine the exact period of the revolution of one of these bodies, he began to observe its successive eclipses, and to notice the time between them, as the means of ascertaining its velocity and motion. To attain the greatest possible precision, he continued his

investigations through successive intervals. But Roemer had not done this many weeks before he was conscious that the time of the eclipse was a little *later* than it ought to be, according to computation founded upon previous observations; and it gradually became *still later*, till, at the expiration of six months, it was sixteen minutes *behind* the time computed from his first reckonings. After this period, continuing his watchings, the eclipse was found to be occurring gradually *not so late* as before, till at the close of another six months, the whole difference of sixteen minutes between the computed and observed times was done away with.

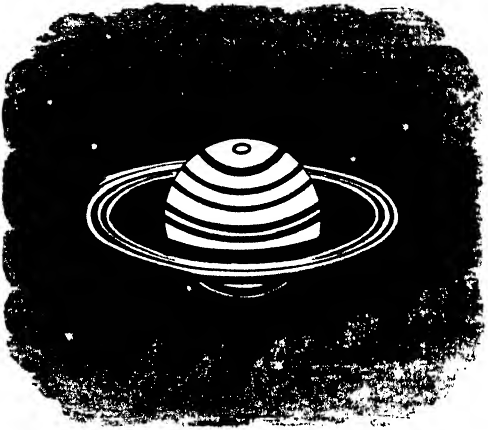
In explanation, the happy thought struck Roemer, that the observed time of an eclipse is never in any case the true time, but an interval afterwards, which light requires to reach the eye of the terrestrial spectator; and that the phenomenon of the eclipse gradually becoming *later*, and *not so late*, was simply occasioned by his own removal with the earth in its orbit to a varying distance from the system of Jupiter. Thus



let A B C D represent the earth in different positions of its orbit; and J Jupiter surrounded by his satellites. It is obvious that when at A the earth is nearer the great planet by the whole diameter of its orbit, than when at C. Now this change of distance would make no difference in the observed time of an eclipse if light were propagated instantaneously; but as there is the difference of sixteen minutes, light requires that time to travel over the space, amounting to 190 millions of

miles, which gives it a velocity of 198,000 miles a second.

The rate at which light travels is the swiftest movement in nature with which we are acquainted; and few greater feats have been performed than to measure the motions of an element that literally leaps over the gulf of nearly two hundred thousand miles while the pendulum makes an oscillation. It is estimated that the time consumed by the electric current in traversing the distance between Greenwich and the Strand, say seven miles, is the $\frac{1}{3000}$th part of a second; and experimental inquiry on some of the long telegraphic lines gives it about the same velocity. But this is scarcely one-ninth the rapidity of light. Yet it is a striking and obvious conclusion from the progressive motion of light —so vast is the scale of the universe—that we have no certain proof of the present existence of the sun or a star. If the orb of day were shorn of radiance at a given moment, we should not be conscious of the change till upwards of eight minutes after the catastrophe, as his expiring rays would not reach us under that interval. If Jupiter were to perish, announcement would not be made to us of the event under forty minutes; if Saturn, it would be an hour and a quarter; and if Uranus, two hours and a half. But there are stars so vastly remote, that with all its astonishing speed, the light that reveals them at the present instant only tells the tale of their existence, not so much in days that are gone, as in ages past, while the orbs themselves may have been extinguished for centuries by the power which lit them up in the awful distance.



CHAPTER X.

THE ARCHITECTURE AND SYSTEM OF SATURN.

Effect of Change of Distance—Telescopic Aid-Old Opinions of Saturn—First Observations of Galileo—Three Bodies apparent-Changed Appearances—Discoveries of Huyghens-Annular Appendage announced-Change of Aspect Explained-Two Rings Observed-Discoveries of Cassini—Determinations of Sir W. Herschel-Position of Saturn in the Rings—Recent Observations-Bond and Lassel-Satellites of Saturn—Magnitude of the Planet—Dimensions of the System—Thickness of the Rings-Solar Light and Heat.

An object remarkable in itself, yet scarcely to be discerned in the haze of the remote horizon, commands no admiration, and excites no interest, unless we know beforehand what it is. But whether this knowledge be possessed or not, its true character is surely revealed on a near approach; and frequently the indistinct and

insignificant speck discloses stately proportions and a grand architectural character. It may be a castle of the olden time, with towers, turrets, and battlements, once inhabited by a baron bold; or a mansion of the Tudor age, with halls, corridors, galleries, oriel windows, tennis-court, and all the appurtenances deemed necessary by power, pride, or opulence. From the moment that this discovery is made, though the edifice is never approached again, and is only seen afar off as a puny thing, we think not of it as it appears in the distant landscape, but associate with it ideas in harmony with its real dimensions and actual details. The speck has for ever ceased to be one in our minds. It is a grim castle, or a noble mansion. Now precisely analogous is the effect which the telescope has produced with reference to the orbs of the universe. Though the interval between us and them remains really the same, yet it has been practically abridged by the instrument, for its optical power is equivalent to a corresponding lessening of the distance. Accordingly, since it was applied to celestial observation, a magic change has been wrought in human conceptions of the bodies in our system, as though a bridge had been partially thrown over the great gulf of space, which has brought us millions of miles nearer to their orbits; and we no longer think of them as they appear to the unassisted vision, but as exhibited by instrumental means.

Among the corrections offered to thought by this practical approximation, perhaps the most striking is the change of ideas with reference to the planet Saturn, the sixth in order from the sun. It was for ages viewed as having no special claims to notice, and merely regarded as a dull, dreary, malignant star, with

a leaden hue, and a snail's pace; but it is now familiarly known as one of the most engaging and extraordinary objects in the heavens. Owing to this slowness of motion, the symbol of the planet was adopted as the hieroglyphic of lead. But though of very portly proportions, Saturn is really a light, buoyant personage, as to the material of which he is composed, for the density is little more than that of cork. Instead, therefore, of sinking like lead in the mighty waters, he would float upon the liquid, if an ocean could be found sufficiently capacious to receive him. John Goad, the well-known astro-meteorologist, declared the planet not to be such a "plumbeous blew-nosed fellow" as all antiquity had believed, and the world still supposed. But it was the work of others to prove it.

For six thousand years or so, Saturn concealed his personal features, interesting family, and strange appurtenances—the magnificent outbuildings of his house —from the knowledge of mankind. But he was caught at last by a little tube, pointed at him from a slope of the Apennines, the holder of which, in invading his privacy, cared not to ask leave, and deemed it no intrusion. Again and again, with the utmost pertinacity, the tube was held up; for it had disclosed something, not known before, respecting the planet's quarters, which the holder wanted to find out more clearly. From that period, through nearly two centuries and a half, they have been diligently examined, and remarkable disclosures have been made. It is not, however, certain that we yet know the real number of the Saturnian family, and the full structure of his attendant rings.

Armed with a telescope of superior power, Galileo, in the year 1610, surveyed the planet, and found it

apparently of an oblong form, somewhat like the snape of an olive—thus ○. This was the first peculiarity noticed. But using an instrument of greater power, in the same year, it appeared to be, not single, but composed of three bodies, which almost touched each other, and constantly maintained the same relative position. He described the three bodies as arranged in the same straight line: the middle one was the largest, and the two others were situated respectively on the east and west sides of it. "They are," says he, "constituted of this form, oOo;" and he goes on to remark exultingly, "Now I have discovered a court for Jupiter (alluding to his satellites), "and two servants for this old man, Saturn, who aid his steps, and never quit his side." The discovery he announced to Kepler, under the veil of a logograph, which sorely puzzled him. This was not to be wondered at, for it ran—

Smaamrmilmilpoetalevmibrnenvgttaviras.

Restoring the transposed letters to their proper places, we have the sentence, *Altissimum planetam tergeminum observavi*—"I have observed the most distant planet to be threefold."

However great the surprise of the observer, it was soon followed by the utmost astonishment and perplexity. He found, that while the lateral bodies appeared immovable, both with respect to each other and the central body, they were constantly diminishing in their apparent magnitudes. They continued to grow less and less through the two following years, at the close of which they vanished altogether. The old man, or the planet, now seemed simply round, while the two servants provided for him, as if disliking their master or the place, had fled. The disappearance was

perfectly unaccountable; but if it occasioned perplexity, it created not a little alarm; for the observer justly feared that, being unable to explain the circumstance, his enemies would take advantage of it to discredit all his observations, as having no foundation in nature. This was a trial somewhat hard to bear. "What," he remarks, "is to be said concerning so strange a metamorphosis? Are the two lesser stars consumed, after the manner of the solar spots? Have they vanished and suddenly fled? Has Saturn perhaps devoured his own children? or were the appearances indeed delusion or fraud, with which the glasses have so long deceived me, as well as many others, to whom I have shown them? I do not know what to say in a case so surprising, so unlooked for, and so novel. The shortness of the time, the unexpected nature of the event, the weakness of my understanding, and the fear of being mistaken, have greatly confounded me." Galileo, however, witnessed the old appearances again, and saw them renew their changes; but he never understood the cause of the vicissitudes, for the secret was not solved in his time.

As increased optical power was brought to bear upon the planet, former representations of its aspect were greatly modified. Thus the two lateral bodies, instead of being round, seemed to be two luminous crescents. Instead, also, of being detached from the central body, keeping a respectful distance, as servants in the presence of the master, they appeared to be actual parts of the dignitary himself, protruding as side limbs from him. The crescents were apparently attached by their cusps to the central body, as if forming two *ansæ*, or handles, to it; but they were so constantly, though slowly, altering their conformation, and giving a

different aspect to the planet, that while astronomers were perplexed about the meaning of the phases, they were at some loss for terms to define them. Seldom has an object been distinguished by such a variety of names, more or less uncouth, suggestive of change of form, as Saturn. At one time he was pronounced "monospherical," at another, "trispherical;" now "spherico-ansated," then "elliptico-ansated," and anon "spherico-cuspidated."

At last, with a superior telescope, Huyghens took the mysterious personage in hand, and became somewhat intimately acquainted with him. He first discovered a satellite, a kind of eldest son, the brightest member of the family. This was in 1655. In the following year, he announced, in a small tract, the true constitution of Saturn, though in a most unedifying way, for it was conveyed in the following array of letters, which might baffle a decipherer of the Assyrian inscriptions:—

aaaaaaa ccccc d eeeee g h iiiiii llll mm nnnnnnnnn
oooo pp q rr s ttttt uuuuu.

Properly arranging the letters, as the author afterwards did, they form the sentence, *Annulo cingitur, tenui, plano, nusquam cohærente, ad eclipticam inclinato*—"The planet is surrounded by a slender flat ring, everywhere distinct from its surface, and inclined to the ecliptic." He fully developed his conclusion in a treatise, and showed how beautifully and convincingly it explains the various phases of the planet, especially its simply round appearance, which so sorely troubled Galileo, after having seen it, as he thought, triple. The ring is occasionally invisible, and the planet then appears spherical, like the sun or full moon, owing to

three causes: when the edge only is turned to us, it is too thin to be seen by the terrestrial spectator; for the same reason it is invisible when the edge, being turned to the sun, is alone enlightened by the solar rays; and it disappears when the unilluminated side is turned towards the earth. This remark applies to all observers, except the few who are in command of the mightiest telescopes. Huyghens predicted that Saturn would appear ringless in the summer of 1671; and the annulus totally disappeared towards the end of May. "In 1819," says Admiral Smyth, "I was much amused in showing the denuded orb to some islanders in the Adriatic, with the same instrument which had, the year before, shown them what they called 'a star with a hoop round it.'"

The next step towards unfolding the architecture of Saturn was taken by Mr. W. Ball and his brother, Dr. Ball, of Minehead, in Devonshire, who, on the 13th of October, 1665, first saw the ring double, divided into two portions by a dark elliptical band. Cassini, a Frenchman, verified the observation. It has since been amply confirmed and illustrated, so that the planet is surrounded by two concentric rings, separated from each other by a space, indicated by the dark band, through which the open heavens are visible.

Another satellite, picked up by Cassini, in 1761, refuted a prediction, and illustrated the folly of forming opinions without a basis for them in the facts of nature. But some of the strongest minds of that age were shackled by ancient notions respecting the harmony of numbers and similar fancies. Hence, when Huyghens discovered his satellite, he asserted that no more would be found, because the number then known in the system, six, corresponded to that of the primary

planets, and twelve was allowed on all hands, to be a perfect number. The fallacy of this assertion was proved by the new discovery; and it was further exposed in 1684, when three more Saturnian moons were detected by the same observer. Five dependent orbs, with two hoops, were then known to be in attendance upon the primary, forming a goodly household. But Huyghens, as if to make up for his former unfortunate conclusion, now surmised that the family would be increased; and he had this time a valid reason to assign for the suspicion. Perceiving that the interval between the orbits of the fourth and fifth satellites was disproportionately greater than between any of the rest, he remarked of this vacuity, "Here, for aught I know, may lurk a sixth gentleman." So it has turned out. But the "gentleman" found lurking in this place ranks as number eight, instead of six. Cassini dubbed his prizes, *Sidera Lodoicea*, in honour of his sovereign, Louis XIV.; but the astronomical world properly refused to sanction this tribute of flattery to the *Grand Monarque*. All the five satellites were discovered at the times of the disappearance of the rings. This was doubtless owing to the planet being most intently watched at those intervals, in order to mark the phenomenon, as well as to the greater facilities offered for observation by the absence of the encumbering appendage.

The elder Herschel long and severely interrogated the planet, with memorable results. He sat down to the task with his wonted zeal, in the year 1775, and pursued it with unflagging industry over more than a quarter of a century. Fluctuating dark bands upon the disk, noticed by some of his predecessors, analogous to those of Jupiter, were assiduously watched, and

gave evidence of an atmosphere of considerable extent, subject to great disturbance. These shady belts are doubtless the opaque surface of the orb, seen through regions of the atmosphere comparatively free from clouds, while the brighter intervening zones are dense accumulations of vapour which possess a superior power of reflecting the solar light. The fact of the planet's rotation was established, with its period, and the greater divergence of the huge globe from perfect sphericity than in the instance of the other planets, an obvious consequence of a more rapid axial rotation, and lighter material. The same investigator first remarked the superior brilliancy of the polar regions. This is least perceptible after they have been long exposed to the influence of the solar rays; and most distinct when just emerging from the long night of their polar winter. Whether the appearance arises from the presence of snow, at its minimum at the former period, and its maximum at the latter, or whether from fluctuating vapours suspended above the surface, the existence of an atmosphere is in either case necessarily implied.

On the 27th of August, 1789, having just completed the forty-feet reflector, Herschel discovered a fresh satellite, making the number then known six. It was the first night of the application of the giant instrument to the heavens. The event was thus recorded:—"In hopes of great success with my forty-feet speculum, I deferred the attack upon Saturn till that should be finished; and having taken an early opportunity of directing it upon Saturn, the very first moment that I saw the planet, I was presented with a view of six of its satellites, in such a situation, and so bright, as rendered it impossible to mistake, or not to see them."

In less than a month afterwards a seventh satellite, the one nearest the primary, a most difficult test object, was caught.

The remarkable appendages of the planet did not escape a rigid scrutiny; and Herschel may be said to have been the first to place beyond doubt the duality of the ring. He also ascertained the fact of the rotation of the rings, which had been inferred from the laws of mechanics, as necessary in order to generate a centrifugal force sufficient to balance the attraction of the planet, and prevent precipitation upon its surface. He inferred from his observations that an atmosphere envelops them; that superficial irregularities mark their construction; and he was the first who discerned the shadow cast on the planet, when the edge, being turned towards the earth, is invisible. It was also remarked by this distinguished man, that the light of the rings is brighter than that of the planet; and that the brightness of the interior one gradually diminishes inwards, till at the inner edge it is scarcely greater than that of the shaded belts of the orb. Seen under a high magnifying power, Saturn exhibits no leaden hue, but a light of a yellowish tinge, while that of the rings is white. The interior ring is brighter than the exterior. The difference between them in this respect has been illustrated by that which subsists between unwrought and polished silver.

The position of the planet is not precisely central in relation to the rings, but a little to the westward. This eccentricity, after being surmised, was proved by Struve, in the year 1826. Instead of the centre of gravity of the rings coinciding with that of the planet, the former describes a very minute orbit around the latter. Insignificant as this fact may appear, it is essential to the

conservation of the system; for had the two centres exactly coincided, it can be shown that any external force, such as the attraction of a satellite, would subvert the equilibrium of the rings, and precipitate them upon the orb. How true it is, that the same Lord, who by wisdom hath founded the earth, by understanding hath established the heavens! It has recently been ascertained that the outer ring is in itself multiple; and that there is either a distinct semi-transparent appendage nearer the planet than the old inner ring, or a continuation of the latter, very much inferior to it in brightness.

An eighth satellite, discovered in the year 1848, completes the Saturnian family as at present known. It was found on the very same day, the 19th of September, by two astronomers residing in different hemispheres, separated from each other by the broad Atlantic—Mr. Lassel, of Starfield, Liverpool, and Professor Bond, of Cambridge, in the United States. The two discoveries ran together as follows:—

LASSEL.	BOND.
Sept. 16.—No observation.	*Sept.* 16.—Notices a small star nearly in the plane of the ring between Titan and Japetus. Regards it as accidental, but records its estimated position with regard to Saturn.
Sept. 18.—Observes two stars near Saturn, of which he was unable to determine which was Japetus,	*Sept.* 18.—Notices the same object, and measures again, more carefully, but still "scarcely suspected its

the satellite he was looking for. Makes a careful diagram of the system, and of the neighbouring stars.	real nature."
Sept. 19.—Establishes that both stars share the motion of the planet; that one is Japetus, and the other a new satellite.	*Sept.* 19.—Finds that the new object partakes in the retrograde motion of Saturn, and establishes the satellite.

Thus, while Mr. Bond first saw the satellite as a star, he only discovered its true character on the same night with Mr. Lassel; and as neither could claim priority of observation, it was properly remarked, that the English should say it was discovered by Bond and Lassel, the Americans by Lassel and Bond. But it is only just to state, that while Mr. Bond, a professional astronomer, had the use of a magnificent refracting telescope at a national observatory, Mr. Lassel, a merchant, used a Newtonian reflector of his own construction, at his own residence. The Council of the Astronomical Society, in awarding to the latter the gold medal for the year 1848, observed: "The simple facts are, that Mr. Lassel cast his own mirror, polished it by machinery of his own contrivance, mounted it equatorially in his own fashion, and placed it in an observatory of his own engineering. A private man, of no large means, in a bad climate, and with little leisure, he has anticipated or rivalled, by the work of his own hands, the contrivance of his own brain, and the outlay of his own pocket, the magnificent refractors with which the Emperor of Russia and the citizens of Boston have endowed the observatories of Pulkowa and the Western Cambridge."

In accordance with the suggestion of Sir John Herschel, the names of the Titanian divinities are now commonly applied to the satellites. In order of distance from the primary, they rank as follows:—

SATELLITE.	DISCOVERER.	DATE.
1. Mimas	W. Herschel	1789
2. Enceladus	W. Herschel	1789
3. Tethys	D. Cassini	1684
4. Dione	D. Cassini	1684
5. Rhea	D. Cassini	1684
6. Titan	C. Huyghens	1655
7. Hyperion	Bond and Lassel	1848
8. Japetus	D. Cassini	1671

The first, second, and third satellites are much nearer the planet than the terrestrial moon is to the earth; the fourth is also slightly nearer; but the eighth, the most remote, is upwards of two millions of miles from the primary, or ten times the distance of our moon from us. Nothing is known with exactness respecting their magnitude, except that the sixth, Titan, is the largest, and is perhaps but little inferior to the planet Mars. Their periods of revolution range from one to seventy-nine days.

The wonderful orb of Saturn has a diameter of 75,000 miles, and a volume which is more than eight hundred times the size of the earth. Yet the planet is carried round upon its axis in about ten hours and a half, moving with a velocity at the equator which is more than twenty times greater than the earth's velocity of rotation at the same part of its surface. The dimensions of the whole system are in round numbers as follows:—

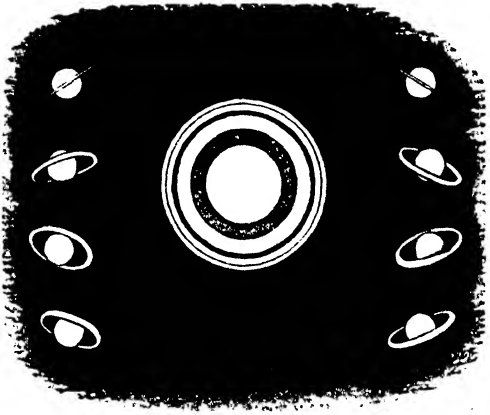
	MILES.
Diameter of the Planet	75,000
From the Planet to the Old Inner Ring	20,000
Breadth of the Inner Ring	17,000
Interval to the Outer Ring	1,800
Breadth of the Outer Ring	10,500
Exterior Diameter of Outer Ring	172,000
Diameter of the Orbit of the Outer Satellite	5,000,000

Yet so vast is the distance to which this mighty system is removed from us, that the disk of our moon is more than sufficient to hide it altogether from our sight.

The annular appendages of the planet have a very inconsiderable thickness, perhaps not amounting to more than from one to two hundred miles. Such indeed is their thinness, that when the minutest of the satellites, which can only be reached by telescopes of extraordinary power, appears on the edge, it projects on the opposite sides, above and below. Herschel once saw his two little moons in this position, as beads moving along a line of light, "like pearls strung on a silver thread." It is owing to this extreme thinness that the rings are not discernible by ordinary instruments, when the earth being in their plane, only the edge is presented to us. This occurs twice in every revolution of the planet round the sun, at opposite points of its orbit, and at intervals apart from each other by about fifteen years. The last instance was in the year 1848, and the next will be in 1863. In the course of the periodical revolution, the rings are seen under very varying aspects. Alternately we behold one side and then the other; and oval forms of different ellipticity are presented. These are the phases of Saturn, unknown to the shepherd-astronomers of Chaldea, the star-gazers of Egypt, Greece, and Rome, the astrologers of the middle ages, Copernicus and Tycho Brahe, who were only acquainted with one of the most surprising objects in the solar universe, as a dull nebulous star, slowly moving in the heavens.

Placed in the system at nearly twice the distance of Jupiter, or 906 millions of miles from the sun, Saturn has an enormous orbital path to describe, and occupies a period of 29½ terrestrial years in accomplishing his

appointed revolution round the central globe. In consequence of the immense distance, the sun, as seen



PHASES OF SATURN.

from the planet, will dwindle down to an orb of one-ninth the apparent diameter exhibited to us; and will afford little more than one-eightieth of the light and heat supplied to the earth. But as some compensation, the solar glory returns twice in a terrestrial day to the meridian of any place on the Saturnian globe, owing to the velocity of rotation, while a plentiful supply of reflected light is furnished by means of the satellites and rings. The former by their number, and the latter by their extent, will splendidly adorn the night-sky of the planet.

CHAPTER XI.

URANUS—N

Aspect of Uranus—Diameter, Distance, and Period—Proportion of Solar Light and Heat—Satellites of the Planet—Their Peculiarity—Discovery of Uranus—Previous Observations—Sir W. Herschel—His Arrival in England—Residence at Bath—Patronized by George III.—Settlement at Slough—The Forty-Feet Reflector—Space-Penetrating Power of Telescopes—Description of the Giant Reflector—Death of Herschel—His Sister—Neptune—Unexplained Perturbations of Uranus—Inference from them—Researches of Adams and Leverrier—Discovery of Neptune—A Satellite Discovered—Cincinnati Observatory—Old Observation of Neptune—Magnitude and Distance of the Planet—Details of the Solar System—Its Great Scale.

THE far remote orb of Uranus, recently regarded as defining the outer boundary of the system, is scarcely to be distinguished by the naked eye, though eighty-eight times larger than the earth. But under favourable circumstances, as when the sky is very clear, and the moon absent, a practised gazer, knowing where to look, may detect him, appearing commonly as a star of the sixth magnitude, shining with a subdued light. Viewed with high magnifying powers, a distinct and well-defined disk is exhibited, which presents a uniform greyish tint, without the slightest symptom of spots, belts, or rings. The planet has a diameter of 35,000 miles, and is at the mean distance of 1800 millions of miles from the sun. His period of revolution comprises eighty-four of our years. Hence, as his place in the system was only discovered in the year 1781, a single revolution since that date has not yet been quite accomplished. But slow as is the apparent pace of

Uranus, the actual rate amounts to sixteen thousand miles an hour, from which the immense length of the orbital march may be inferred. Owing to the enormous distance of the planet, the proportion of light and heat received from the sun is 324 times less than that enjoyed by the earth; and the diameter of the solar disk appears eighteen times less than it does to us. But though thus apparently reduced to a speck, the illuminating power of the sun to that remote world will be equal to the light afforded by three hundred of our full moons, while we know certainly, with reference to the temperature of the earth's surface, that it does not depend solely upon the direct rays of the sun, but on the condition of its atmosphere, and the internal heat of its mass. Nothing is known of the physical constitution of Uranus, nor is it likely that this will be illustrated, on account of the vast intervening distance. Though stated by some to rotate upon an axis in nine and a half hours, the fact of the rotation itself is by others considered to be doubtful.

Uranus is attended by six satellites, detected at different intervals by Sir W. Herschel, the discoverer of the planet, and named according to the order of their distances from the primary.

Satellite.	Date of Discovery.	Periodic Time.		
1st	January 18, 1790	5d.	21h.	25m.
2d	January 11, 1787	8	17	1
3d	March 26, 1794	10	23	4
4th	January 11, 1787	13	11	5
5th	February 9, 1790	38	1	49
6th	February 28, 1794	107	16	40

The existence of two of these bodies still rests upon the sole authority of the discoverer; and it has only been since the year 1828 that his observation of the other four has been verified. In that year, his son, Sir

John Herschel, caught sight of the two discovered in 1787, after having prepared himself by keeping his eye in utter darkness for a quarter of an hour. They are such faint objects as to require telescopes of the greatest perfection to render them barely discernible. There are, however, two remarkable peculiarities well ascertained respecting these bodies: they revolve in orbits which are nearly perpendicular to the plane of the earth's orbit; and to the surprise of all astronomers, their motion in them is retrograde, or from east to west, contrary to the order of movement of all other bodies yet noticed in the system, primary and secondary.

It was on the evening of the 13th of March, 1781, while Herschel was examining some small stars in the feet of Gemini, that his attention was attracted towards a particular star, which appeared to have a diameter sensibly larger than the others. This was more perceptible on using high magnifying powers; and the object was at first conceived to be a comet. It was speedily watched by the whole astronomical world, and soon recognised as a superior planet, resembling the rest of the system in every possible point, but doubling its extent, being twice the distance of Saturn from the sun. Herschel named the new planet the Georgium Sidus, in honour of his munificent patron, George III. His own name, as the discoverer, was applied to it by some foreign astronomers. But the general feeling being in favour of a mythological term, it was called Uranus, the fabled sire of Saturn; and this is now the universally accepted denomination. It is remarkable that the planet had been observed on many previous occasions by astronomers, but supposed to be one of the stars. Thus it was seen in 1690 by

Flamstead, the first Astronomer Royal, who recorded it as a star of the sixth magnitude; and from that year down to 1781, its position was determined no less than nineteen times, under an erroneous impression of its real nature. Four observations by Lemonnier were made on four consecutive nights; and if it had only occurred to him to compare them together, he could not have failed to anticipate Herschel in the discovery of the planet.

It has not been to our national credit in time past, that the men who have been distinguished merely by connexion with scenes of martial strife have enjoyed a larger measure of public admiration, while their career has found a more speedy chronicle than those who have won distinction by enlarging the bounds of knowledge, promoting the interesting or useful sciences, and illustrating the grandeur of the universe. Especially have the lives of our physical inquirers been overlooked until a very recent date. Newton had lain in his grave a hundred and four years, Flamstead a hundred and sixteen, and Bradley seventy years, before justice was done to their memories by competent biographies from the pens of Brewster, Baily, and Rigaud. Though public sentiment has immensely improved in its estimate of the value of actions, yet the great self-taught optician and astronomer of the last century, Sir W. Herschel, still remains without a similarly creditable record. The materials for it are abundant, while his claims are undoubted; and few more interesting volumes would be embraced by our literature than a careful analysis of his labours, as he sounded the remote profundities of the firmament, and ranged unwearied among its abysses. His mode of operation marks the original, philosophic, and great mind. In-

stead of quarrelling with contemporaries, and contesting received opinions, he proceeded unostentatiously to examine for himself, mingling boldness with modesty, and thirsting after large and general views with the scrupulous observation of appearances, and dutiful obedience to their intimations. His rise forms a grand epoch in astronomy. Previously, all accessible space seemed to be circumscribed by the planetary orbits, which constituted, in general, effective bounds to scientific inquiry. Astronomers had seldom ventured to grapple with greater remoteness. They were much upon the same level with the crowd of star-gazers, content to admire their beauty, and confess their mystery. But Herschel fearlessly, yet quietly, overleaped the limits of his predecessors and contemporaries, attempted to lay open the hitherto unexplored recesses of the sidereal world, and succeeded to no mean extent in lifting up the veil from its economy.

Without intending to trace the scientific career of Herschel, a few particulars of his life may be given, appropriately in this place, as the discoverer of Uranus.

He was the second son of a musician at Hanover, born November 15, 1738, and brought up to his father's profession. Being placed in the band of a Hanoverian regiment of guards, he either came over with it to England, or, according to some accounts, arrived alone in quest of fortune, when about twenty years of age, immediately before George III. ascended the throne. He settled successively at Durham, Halifax, and Bath, following his musical vocation, but turned his attention to astronomy in the latter city. Having a decidedly mechanical genius, with some

knowledge of optics, and being destitute of means to purchase a telescope of adequate power, he resolved upon the construction of one with his own hands. The earliest, a five-feet Newtonian reflector, with which he observed the satellites of Jupiter, and the ring of Saturn, was completed in 1774. Herschel was indefatigable in arming himself with instrumental assistance; and became in fact a telescope maker upon an extensive scale, not for profit, but the better to see with his own eyes the wonders of planetary and sidereal space. In order to secure a good instrument, he finished an immense number of specula, selecting the best for use. The labour and anxiety involved in casting, grinding, and polishing, can only be appreciated by those who are practically acquainted with the processes. Altogether, he accomplished the construction of two hundred specula of seven-feet focus, one hundred and fifty of ten-feet, and above eighty of twenty-feet, besides a number of the Gregorian form, amounting to a total of not less than five hundred.

At Bath, the city of fashion, while a humble organist, he discovered the planet; and this extension of the system established his European fame. It attracted the attention of George III., who attached him to his court, in the capacity of private astronomer, with a salary of £400 per annum, and the honour of knighthood. This munificent patronage led him to remove to Datchet, and afterwards to Slough, near Windsor, where he resided to the end of his days. He married a widow lady, Mrs. Mary Pitt, and the present Sir John Herschel is the heir of his name and fame.

The new resident at Slough had not long been located there before he projected the construction of a

telescope upon a scale which the most sangine mechanicians had never anticipated. For him to entertain a design was resolutely to set about its accomplishment; and difficulties in the way only called forth the unconquerable ardour of his mind. Though repeatedly foiled in the attempt to cast great specula, which cracked in the act of annealing, and met by other mischances, he persevered till success crowned his efforts. The design being submitted, through the medium of Sir Joseph Banks, to the king, he generously offered to defray the whole expense; and, thus encouraged, the task of constructing a forty-feet reflector was commenced towards the close of the year 1785, and completed by the middle of 1789. Though considerably surpassed in power by some modern instruments, Herschel's great telescope was an immense advance ahead of its predecessors—a giant after pigmies. The polished, or effective surface of the speculum, or object-glass, was four feet in diameter. It was three inches and a half in thickness, which was uniform in every part, and weighed nearly 2,118 pounds. The metal was composed of pure copper and tin, in the proportion of 32 copper, and 10·7 of tin. Had the mirror reflected all the light which fell upon it, it would virtually have been an eye with a pupil of four feet diameter, and would have been more powerful than the human eye in the same proportion as its enormous disk exceeded the contracted surface of our pupil. It resolved the faint and confused into definite form on sweeping the firmament; reached the inconceivably distant; and showed nearer objects clothed with inexpressibly beautiful or overpowering lustre. Intent on discovery in the remote regions of the universe, Herschel seldom looked at the larger stars, and espe-

cially avoided them, as their blaze might endanger his eyesight. But on one occasion, while casually sweeping a portion of the heavens, he tells us, "the appearance of Sirius announced itself, at a great distance, like the dawn of the morning, and came on by degrees, increasing in brightness, till this brilliant star at last entered the field of the telescope with all the splendour of the rising sun, and forced me to take my eye from the beautiful sight."

To one of his ten-feet telescopes Herschel assigned a space-penetrating power of 28½, or a capability of descrying a star 28½ times further off than the naked eye can reach. To one of his twenty-feet telescopes he gave the power of 61; another, of superior construction, he rated at 96; but the space-penetrating power of the giant instrument he estimated at 192. We may gather precise ideas from these figures. Thus he computed that the depth to which the naked eye can penetrate into space extends to stars of the twelfth order of distances; that is, it can descry a star twelve times the distance of those luminaries which, from their superior magnitude, we conclude to be the nearest to us. Though his accuracy has here been questioned, we may assume the correctness of the estimate, and readily calculate the searching power of the instrument by multiplying each of the foregoing numbers by twelve. The result, in the instance of the forty-feet reflector, is 2304; so that, if *that number* of stars ranged in a straight line beyond Sirius, commonly considered the nearest, each being separated by a chasm equal to that which divides his orb from our own, the forty-feet telescope would reach them all. Now the distance of Sirius must be more remote than twenty billions of miles, else there would be a percep-

tible annual parallax. That enormous interval, therefore, multipled 2,304 times, will approximately express the depth to which the instrument penetrated into space.

The tube of the huge reflector was made of iron, and extended thirty-nine feet four inches in length, by four feet two inches in width. It was erected in the open air, with complicated apparatus for movement at the pleasure of the observer; and Slough was rendered by it a common place of pilgrimage to members of the scientific world. Herschel found the solar system with eighteen members, including planets, satellites, and Halley's comet, when his labours commenced; and he increased the number to twenty-seven—a brilliant recompense for time, toil, and care. But his most surprising results were realized in a more distant field than our own part of the universe; and his title to reputation rests chiefly upon the assiduity with which he gauged the starry firmament, resolved the milky-way into a congeries of many millions of stars, discovered binary sidereal systems, the smaller components revolving round the greater, and systems still more complex, consisting of treble, quadruple, and multiple constituents. The principal double stars, as well as the planet Uranus, were found with a telescope of but seven-feet focus, for he never observed with a larger instrument when a smaller would answer the intended purpose, because both time and trouble were thereby saved. Such was the work of the astronomer in favourable weather, night after night, from evening to break of day, till his death, at the advanced age of nearly eighty-four, August 23, 1822.

Caroline Lucretia Herschel, his sister, not only officiated as his amanuensis, but was also an assiduous

independent observer at Slough. With a little Newtonian sweeper, of only twenty-seven inches focal length, she discovered various stellar clusters, and no fewer than five comets, of which that of 1795, in the constellation Cygnus, is now known as Encke's. This lady retired to Hanover, where she survived to the great age of ninety-seven, in the full enjoyment of her mental faculties. A well-earned tribute of respect was paid her by the Royal Astronomical Society in 1835, when she was constituted an honorary member of that body. The council stated, in a report to the general meeting, "That while the tests of astronomical merit should in no case be applied to the works of a woman less severely than to those of a man, the sex of the former should no longer be an obstacle to her receiving any acknowledgment which might be held due to the latter. Your council, therefore, recommends this meeting to add to the list of honorary members the names of Miss Caroline Herschel and Mrs. Somerville, of whose astronomical knowledge, and of the utility of the ends to which it has been applied, it is not necessary to recount the proofs." Miss Herschel died at Hanover, January 9, 1848.

After an existence of rather more than half a century, Slough lost an object which had attracted hosts of visitors, and been viewed with curiosity by many a passing traveller. The frame of the instrument becoming decayed, through exposure to the weather, it was dismantled; and Slough is now chiefly known by the flight of railway trains. But scientific records and local tradition will keep in remembrance its long connexion with the astronomy of England.

NEPTUNE.

We now come to one of the most remarkable achievements of physical astronomy. Soon after the discovery of Uranus, astronomers were perplexed with certain irregularities in the motions of the planet, which could not be deduced from the action of the other bodies in the system. Its orbit had been calculated, with due allowance for the perturbations produced upon it by the masses of Jupiter and Saturn. But after a lapse of years, its actual course was found to be at variance with the theoretical path; and as no error existed in the tables, the idea arose in many minds, that the irregularities might be referrible to some unknown body deep sunk in space, which had escaped the scrutinizing eye of science. M. Bouvard, in France, seems to have been the first person to entertain this surmise, while M. Hansen, another foreign astronomer, with whom he corresponded on the subject, was of opinion that one exterior planet would not account for the discrepancy between theory and observation, and that two planets were necessary for the purpose. In 1834, our countryman, Dr. Hussey, writing to Mr. Airy, suggested the possible existence of some disturbing body beyond Uranus; and was anxious that he should assist him in detecting the invisible planet. In the following year, M. Valz, of Marseilles, addressing M. Arago on the subject of Halley's comet being possibly retarded, made the following interesting remark:—"I would rather have recourse to an invisible planet situated beyond Uranus. Its period, according to the order of the distances, would be at least triple that of the comet, so that the perturbations of the latter would nearly recur at the close of every three revolutions, and the

calculations made for four or five well-established cycles would enable us to trace them. Would it not be admirable to arrive thus at a knowledge of the existence of a body which cannot be perceived?" In 1836, Mrs. Somerville observed:—"The tables of Jupiter agree almost perfectly with modern observations: those of Uranus, however, are already defective, probably because the discovery of the planet in 1781 is too recent to admit of much precision in the determination of its motions, or that possibly it may be subject to disturbances from some unseen planet revolving about the sun beyond the present boundaries of our system. If, after a lapse of years, the tables formed from a combination of numerous observations should still be inadequate to represent the motions of Uranus, the discrepancies may reveal the existence, nay, even the mass and orbit of a body placed for ever beyond the sphere of vision."

The discordance between the theoretic and actual places of Uranus amounted, in the year 1838, to a distance as great as that of the moon from the earth. The planet was describing an orbit greater than that pointed out by theory, as if breaking away from the sun's control. Though some started the conjecture, to explain the anomaly, that the law of gravitation might be relaxed in its rigorous application to a body so remote, while others conceived the deviation might be occasioned by the action of some large satellite, yet the general conviction was in favour of an unknown planet being the disturbing cause. In 1842, when the celebrated astronomer, M. Bessel, was in England, he avowed this opinion to Sir John Herschel; and announced it as his intention, when released from other engagements, to undertake the task of determining the

actual position of the invisible disturber. The inquiry was commenced, but arrested by his own death, with that of Mr. Flemming, a young German, who was entrusted with some of the preliminary calculations. Such was the condition of the problem when it was taken in hand by two young mathematicians, Mr. C. J. Adams of Cambridge, and M. Leverrier of Paris. Neither had any knowledge of what the other was doing; and each believed that he stood alone in the investigation. Both were only known to a limited circle in the scientific world, and not at all to the general public.

Mr. Adams was born in Cornwall. His father, a small farmer, perceiving that the tendencies of the son were not towards an agricultural life, allowed him to follow the impulses of his own genius; and after a school training, he entered at St. John's College, Cambridge, where, at the end of his under-graduateship, he became senior wrangler, and subsequently one of the mathematical tutors. While pursuing his studies, the strange irregularities of Uranus attracted his attention; and he proposed to examine their cause in the year 1841, according to the following memorandum in his note-book under date of July the 3rd:— "Formed a design, in the beginning of this week, of investigating as soon as possible after taking my degree, the irregularities in the motion of Uranus which are yet unaccounted for, in order to find whether they may be attributed to the action of an undiscovered planet beyond it, and, if possible, thence to determine approximately the elements of its orbit, etc., which would probably lead to its discovery." Having taken his B.A. degree in January, 1843, Mr. Adams was at liberty to prosecute his self-imposed task. By the

month of October, 1845, he had solved the intricate problem—the *inverse problem of planetary perturbation* as it has been called—proving beyond a doubt the existence of a planet exterior to Uranus, and assigning to it a place in the heavens, which was afterwards found to be little more than a single degree from its exact position. These results were in the hands of Professor Challis of Cambridge and Professor Airy, the Astronomer Royal at the time stated; and had a diligent search of the heavens been instituted at once, the discovery of the planet would have been made in England. But it was not till more than nine months had passed away, July 29, 1846, that Mr. Challis began the search with the Northumberland refractor.

Meanwhile, Leverrier, who had distinguished himself as a geometer, was busily employed upon the same problem, at the suggestion of M. Arago, and his results, published to the world on the 1st of June, 1848, remarkably coincided with those of Mr. Adams, which, being in manuscript, were only known to a few English astronomers. It was chiefly owing to this confirmation of the latter's investigations, that, at the request of the Astronomer Royal, the services of the Cambridge refractor were enlisted in searching for the theoretical planet; and within a fortnight it was in fact seen by Mr. Challis, who recorded two positions of it, but was not in circumstances immediately to identify the object. On the last day of August, Leverrier announced its mass and actual position with more precision, together with the elements of the orbit; and on the 2d of September Mr. Adams placed in the hands of the Astronomer Royal further researches on the Trans-Uranian planet, correcting some previous

details. On the 10th, at Southampton, in an address to the British Association, Sir John Herschel made use of the memorable words: "The past year has given to us the new planet Astræa: it has done more, it has given us the probable prospect of another. We see it as Columbus saw America from the shores of Spain. Its movements have been felt trembling along the far-reaching line of our analysis with a certainty hardly inferior to ocular demonstration." Not a single telescope abroad had hitherto been directed to the heavens with a view to the actual discovery. But on the 18th, Leverrier wrote to M. Galle, one of the astronomers connected with the Berlin Observatory, requesting his co-operation in detecting the planet; and on the first evening of examination, the 23d, it was recognised, appearing as a star of the eighth magnitude, within less than two diameters of the moon from the predicted place. The object was at once known to be a stranger to that part of the heavens where it was found, therefore a planet, as it was not indicated in a very accurate and recently published map of the region, containing the positions of all stars down to the tenth magnitude. No other observatory in Europe had yet been put in possession of the same facility for detection; and "had it not been," as M. Encke candidly remarked, "for the infinitely favourable circumstances of possessing a map whereon one might be sure to find the positions of all the fixed stars down to the tenth magnitude, I do not think that we should have found the planet."

It was unfortunate for Mr. Adams that the knowledge of his researches was confined entirely to a few of his scientific countrymen, while those of Leverrier were published in the official organ of the Academy of

Sciences. In fact, the name and labours of our countryman were not made known through the medium of the press till the month following the discovery. Hence the honour of it was carried away by Leverrier; but the real merit belongs equally to Mr. Adams, who was undoubtedly the first theoretical discoverer of the new planet. It is one of the greatest intellectual achievements in the annals of astronomy, and the noblest triumph of the Newtonian philosophy. "To detect a planet by the eye, or to track it to its place by the mind, are acts as incommensurable as those of muscular and intellectual power. Recumbent on his easy chair, the practical astronomer has but to look through the cleft in his revolving cupola, in order to trace the pilgrim star in its course; or, by the application of magnifying power, to expand its tiny disk, and thus transfer it from among its sidereal companions to the planetary domains. The physical astronomer, on the contrary, has no such auxiliaries: he calculates at noon, when the stars disappear under a meridian sun; he computes at midnight, when clouds and darkness shroud the heavens; and from within that cerebral dome which has no opening heavenward, and no instrument but the eye of reason, he sees in the disturbing agencies of an unseen planet, upon a planet by him equally unseen, the existence of the disturbing agent, and from the nature and amount of its action he computes its magnitude and indicates its place." By the common consent of the astronomical world, the new planet received the name of Neptune; and was speedily found to be attended by a satellite, first seen by Mr. Lassel on the 10th of October, 1846. This interesting analogy to our own globe, the possession of a single moon, is perhaps only apparent, for there may

be a numerous train hid from observation by the vastness of the intervening distance.

The first discovery of Neptune on the other side of the Atlantic is thus graphically described by the observer, Mr. Mitchell of Cincinnati:—"On learning that Leverrier had communicated to the Academy of Sciences, in August 1846, his final results, I wrote immediately, requesting the computed place of his planet, with such directions as would best guide me in a search, which I desired to make for it with the great refracting telescope of the Cincinnati Observatory. But before my letter reached its destination, the planet had been found, and the news of its discovery soon reached the United States. It was almost impossible for me to credit the statement, and I was almost disposed to believe that the prediction of the planet's position had been mistaken for its actual discovery. With these conflicting doubts, I waited for the coming of night with a degree of anxiety and excitement which may be readily imagined. I had no star-chart to guide me in my search for the planet; I had no meridian instrument with which to detect it by its motion; but I was not without hope that the power of our great telescope might be sufficient to select at once the planet from among the fixed stars, by the magnitude of its disk.

"As soon as the twilight disappeared, the instrument was directed to the point in the heavens where the planet had been found. I took my place at the *finder*, or small telescope attached to the larger one, and my assistant was seated at the great instrument. On placing my eye to the finder, four stars of the eighth magnitude occupied its field. One of them was brought into the field of the large telescope, and critically

examined by my assistant, and rejected. A second star was in like manner examined, and rejected. A third star, rather smaller and whiter than either of the others, was now brought to the centre of the field of the greater telescope, when my assistant exclaimed, 'There it is! there is the planet! with a disk as round, bright, and beautiful as that of Jupiter.' There indeed was the planet, throwing its light back to us from the enormous distance of three thousand millions of miles, and yet so clear and distinct, that in a few minutes its diameter was measured, and its magnitude computed."

Soon after the orbit of Neptune had been determined with sufficient precision to enable astronomers to compute its places backwards, catalogues of the stars were examined, in the expectation of finding, that prior to its discovery as a planet, it had been observed and registered as a fixed star. It was ascertained almost simultaneously by Mr. S. Walker of Washington, and Dr. Petersen of Altona, that a star observed by Lalande on the 10th of May, 1795, entered in the *Histoire Celeste*, since missing, could be no other than Neptune. The observation being marked doubtful, the French astronomers, upon being communicated with, examined the original manuscript of Lalande, preserved in the archives of the Royal Observatory of Paris, when a curious discovery was made. It seems that he first observed the planet as a star of the eighth magnitude, on the evening of the 8th of May, and regularly recorded its place, although the entry does not appear in the printed catalogue. Two days later, on the 10th, not finding the star as laid down, but observing one of the same magnitude very near the place, he suppressed

the former observation altogether as inaccurate, and retained the latter, but marked it doubtful.

Neptune has a diameter of 37,500 miles, and is more than a hundred times larger in volume than our own globe. The planet revolves round the sun at the mean distance of 2800 millions of miles, and defines the outer boundary system, as at present known to us. This distance, instead of being double that of Uranus, does not amount to an excess of two-thirds; and hence the law of Bode, before mentioned, which is generally applicable through the interior of the system, fails wholly at the extremity. Far removed from the source of light and heat, the apparent diameter of the sun, as seen from Neptune, will be thirty times less than as seen from the earth. Across the great gulf of space, the solar globe will have a sensible magnitude about equal to that of Venus, as our morning and evening star. Yet will it dispense a far more glorious illumination, equal to that of many thousands of planets of the same splendour as Venus, owing to the greater intensity of light on the solar surface, while the effect of distance in abridging the lustre and warmth of the sun may be counteracted by the rays being received under different physical conditions adapted to increase their efficiency. We are not to regard our world as a pattern globe, which has exhausted the resources of Jehovah, but as a unit among myriads, which also exhibit the wisdom and power of their common Maker. Seated so far out in space, Neptune has an orbit of 16,000 millions of miles to describe in moving round the sun, and a periodic time of 164⅓ years. Hence, reckoning from the date of the discovery of the planet, 1846, it will not be till the year 2011

that a single revolution is accomplished. Since the birth of Christ there have been 1858 revolutions of the earth, 22 of Uranus, and but 11 of Neptune.

Having reached the limit of the known planetary worlds, the principal details of the system may be tabulated, for the sake of convenient reference.

	Diameter. Miles.	Distance from Sun. Millions of Miles.	Period of Revolution. Days.	Velocity in Orbit. Miles per Hour.	Period of Rotation.
					h. m.
Sun . . .	882,000	—	—	—	
Mercury .	3,140	37	88	110,725	24 5
Venus . .	7,800	69	225	81,000	23 21
Earth . .	7,912	95	365	68,890	23 56
Moon . .	2,153	—	27	2,265	—
Mars. . .	4,100	145	687	55,812	24 39
Planetoids					
Jupiter.	88,640	494	4,332	30,203	9 55
Saturn . .	75,000	906	10,759	22,306	10 29
Uranus. .	34,500	1,800	30,687	15,730	
Neptune .	37,500	2,800	60,126	12,570	—

This scheme of worlds is distinguished by certain great characteristics. All the planets have the shape of oblate spheroids; they revolve round the sun from west to east; they rotate upon their axes in the same direction; their orbits are nearly circular; their paths are but slightly inclined to each other; and, with the exception of the satellites of Uranus, all the secondary bodies follow the same general laws. Their movements appear irregular and involved in the extreme, as seen from the earth, because we view them out of the centre of their motions, and are in

movement ourselves. But could we stand upon the sun, and command a view of the system, we should see the dependent worlds following a course as simple and harmonious as that of equestrians in a circus, riding with different velocities around the centre of the arena at different distances from it. We should see the inner planets, Mercury, Venus, the Earth, and Mars, describing lesser circles with greater speed than the outer, Jupiter, Saturn, Uranus, and Neptune. The former, therefore, would seem to overtake the latter several times in the course of their revolution; but all would appear making a steady and constant advance in rings round a common focus. This uniformity is manifestly the result of that lofty wisdom and power which planned all things at "the beginning of the creation," and its permanence from "the days of old, the years of many generations," distinctly proclaims the perpetual providence of God.

It is difficult to realize approximately the great scale of the system immediately around us. We can form a distinct conception of distances which we are accustomed to travel; and a person who has made a voyage round the globe will readily entertain a commensurate idea of thousands of miles. But millions of miles involve an extent of space which so far transcends the scenes of terrestrial locomotion, that the mind is confounded by the effort to embrace the range. It is only by calculation upon a reduced scale, and comparison with familiar standards, that we can illustrate to ourselves the vast dimensions of the planetary universe. Adoping this expedient, London may be taken to represent the sun, and one mile to express a million of miles. Then the orbit of Mercury will be a circle passing within the distance of Rochester, Guildford,

Reading, and Bedford, from the metropolis, while the orbit of Neptune will be a ring circumscribing nearly the whole of Europe, with the North Pole, the greater part of the North Atlantic, and of Northern Africa. Again, a railway train in constant movement, at the rate of thirty miles an hour, would pass round the earth at the equator in 35 days; but it would require 365 years to move from the earth to the sun; 10,950 years to move from the sun to Neptune; 21,900 years to compass the diameter of the system; and 65,700 years to describe its circumference. Yet this entire system, so mighty in its extent when compared with terrestrial dimensions, is only a "handbreadth" in contrast with the sidereal spaces to which the naked eye ranges, to say nothing of the depths reached by the far-penetrating telescope. What a striking commentary do these facts supply upon those words of Scripture, which illustrate the Divine omnipotence: "Am I a God at hand, saith the Lord, and not a God afar off?" "Can any hide himself in secret places that I shall not see him?" "Do I not fill heaven and earth saith the Lord?"

CHAPTER XII.

COMETS.

Discriminating Features—Scene on the Essequibo—Technical Terms—Popular Superstitions—Comet of 1811—Varying Forms of Comets—Instances of Brilliance—Nuclei and Tails—Extraordinary Dimensions—Physical Constitution of Comets—Their Number—Orbits—Comet of 1680—Its History—Halley's Comet—Return Predicted—Lagrange, Clairaut, Messier—Return verified—Second Return—Story of Halley's Comet—Encke's Comet—Resisting Medium—Biela's Comet—Passes near the Earth's Path—Comet of 1843—The Expected Comet—Supposed Past Visits—False Alarm—Probability and Consequences of Collision.

We have now to consider a very numerous class of bodies of perfectly mysterious constitution and office, some of which are permanently fixed in the solar system, while others are attached to it as periodical visitors, and the majority appear within its limits, retire into the immensity of space, and return no more. Comets, as these bodies are called, are readily distinguished from the planets by several peculiarities. The light by which they shine is in general comparatively pale. They vary in form from globular luminosities to irregular wisp-like shapes; and often totally change their aspect. They either move in immensely elongated ellipses, only one end of which lies within the visible limits of the system, in the majority of cases; or they pass through it in parabolas and hyperbolas—open curves which never return into themselves. While also the planets revolve nearly in the plane of the ecliptic, comets cut it in every direction, and approach the sun from all parts of surrounding space. Their

motion, likewise, is often retrograde, or from east to west, while that of the planets is invariably from west to east.

Early in the year 1843, a scientific European traveller was ascending the course of the Essequibo, one of the noble rivers in the great forest region of South America, with a party of native Indian attendants. For several weeks no sight was gained of either sun, moon, or stars, as a uniform mass of greyish clouds veiled the sky, and the rain descended in torrents. But one evening, while preparing to bivouac for the night, the clouds cleared off towards the south-west, and exposed the deep tropical blue spangled with stars. There was also visible a broad, white, nebulous band, inclining towards the horizon, and stretching half way towards the zenith, the pearly whiteness of which strongly contrasted with the well-developed neighbouring azure. Whether the band apparently rested on the horizon could not be ascertained, as the wall-like forest, near the edge of which the party was encamped, prevented that portion of the heavens from being seen. Sir Robert Schomberg the traveller in question, gazed with amazement upon the object; but soon recognised a comet. His Indian friends looked askance at him, while intently marking the phenomenon themselves. The scene was calculated to fix itself firmly in the memory. Upon a small island in the middle of the river, surrounded by foaming waters, which, opposed in their course by dykes of granite, went thundering away over the black, stony masses, stood a single European, arrested by "a wonder in heaven," in the midst of naked savages, equally impressed, the coppery hue of whose bodies was strongly brought out as the camp-fire threw its gleam upon their figures.

Some stood upright, with arms folded across the breast; others squatted upon the ground; but all eyes were directed to the celestial novelty. For a time no word was spoken, and no sound was heard, but the rush of the struggling stream. At last one broke the silence. "This," said he, "is the spirit of the stars, the dreadful Capishi—famine and pestilence await us." Another called it Cá-poéséiná, "a fiery cloud;" a third, Wæ inopsa, "a sun casting its light behind;" and, as if they had only wanted the utterance of a syllable to give vent to their feelings, the assembled Indians burst into a torrent of declamation, bewailed the appearance of the dreadful Capishi as the precursor of misfortune, and raised with violent gesticulations their arms against the comet.

It must be acknowledged that the terms applied to the apparition by these children of nature are far more picturesque and expressive than those in use with the civilized nations. Our word comet, derived from the Greek, literally signifies "a hairy star," and alludes to the supposed resemblance of the nebulous fringe to the human hair. In defining the details of what may be considered a fully developed cometary body, we speak of a roundish nebulosity as the "head" of the object; of a conspicuous stellar point in it as the "nucleus," answering to a kind of bright central eye, and of a luminous train attached as the "tail." Formerly, the latter appendage was only known as the tail when it follows the head, as when the comet is approaching the sun, while, on receding from the sun, when the train precedes the head, the queue, or pig-tail, became in popular speech the "beard." This position of the appendage is general, but not invariable. The Chinese call it indifferently the "brush." Some of our early

writers speak of "shode stars," meaning comets, the term *shode* being a provincialism for hair. Not a whit better are the phrases of Pliny, referring to diversities of form, as "tun-like," "horn-like," "quoit-like," and "horse-mane-like."

It must be admitted, also, that barbarous tribes have not been singular in viewing unusual appearances in the heavens as harbingers, presages, or causes of terrestrial events, generally of the startling or disastrous class. Civilized communities have been just as prone to the same superstition as the Indians of the Essequibo; and have often been frightened out of their propriety by it. Our national poetry abounds with allusions to the dread portentousness of cometary appearances. Thus Milton fanned the popular prejudice:—

> "Satan stood
> Unterrified, and like a comet burn'd,
> That fires the length of Ophiuchus huge.
> In th' arctic sky, and from its horrid hair
> Shakes pestilence and war."

Byron has likewise—

> "A pathless comet, and a curse,
> The menace of the universe."

A formidable bill of indictment, enumerating high crimes and misdemeanours, appears in the pages of an old versifier:—

> "The blazing star
> Threat'ning the world with famine, plague, and war;
> To princes, death; to kingdoms, many crosses;
> To all estates, inevitable losses;
> To herdsmen, rot; to ploughmen, hapless seasons;
> To sailors, storms; to cities, civil treasons."

But some good as well as evil, and various events of the ambiguous class, have been referred to cometary influence. Popular impressions respecting the supposed terrestrial effects of the comet of 1811—a fine

object in the autumn of that year, well remembered by multitudes—are on record. It was gravely noted, that wasps were very few in number; that flies became blind, and disappeared early; and that twins were born more frequently than usual. The season was remarkable for its bountiful harvest and abundant vintage. Grapes, figs, melons, and other fruits, were not only produced in extraordinary quantity, but of delicious flavour, so that "comet wines" had distinct bins allotted to them in the cellars of merchants, and were sold at high prices. There is, however, no fact better attested, by a comparison of observations, than that comets have no influence whatever in heightening or depressing the temperature of the seasons. The fine fruits and ample harvest of the year in question were, therefore, coincidences merely with the celestial phenomenon, without the slightest physical connexion with it. The Ettrick Shepherd apostrophized the object in the following lines:—

"Stranger of heaven, I bid thee hail;
Shred from the pall of glory riven,
That flashest in celestial gale,
Broad pennon of the King of heaven.

"Whate'er portends thy front of fire,
And streaming locks so lovely pale;
Or peace to man, or judgments dire,
Stranger of heaven, I bid thee hail."

Though the advanced civilization of recent times has led to juster views of cometary apparitions than to regard them as divinely-appointed omens of terrestrial calamity, yet society is apt to be nervous respecting these bodies, as likely to cause some great natural convulsion by collision with our globe, a point to which reference will be hereafter made.

The three prominent features of comets—a head, nu-

cleus, and tail—are seen only in particular instances. The great majority appear as faint globular masses of vapour, with little or no central condensation, and without tails. On the other hand, some have a strongly defined nucleus, which shines with a light as vivacious as that of the planets, so as to be even visible in the day-time. This was the case with one seen at Rome soon after the assassination of Julius Cæsar, believed by the populace to be the soul of the dictator translated to the skies. The first comet of the year 1442 was also so brilliant, that the light of the sun at noon, at the end of March, did not prevent it from being seen; and the second, which appeared in the summer, was visible for a considerable time before sunset. In 1532, the people of Milan were alarmed by the appearance of a star in the broad daylight; and as Venus was not then in a position to be visible, the object is inferred to have been a comet. Tycho Brahe discovered the comet of 1577, from his observatory in the isle of Huene, in the Sound, before sunset; and Chizeaux saw the comet of 1744, at one o'clock in the afternoon, without a telescope. The comet of 1843 was distinctly seen at noon by many persons in the streets of Bologna, without the aid of glasses. The nucleus is generally of small size, but the surrounding nebulosity, which forms the head, is often of immense extent; and the hazy envelope, the "horrid hair" of poetry, is sometimes seen separated from it by a dark space, encircling it like a ring. This was the aspect of the comet of 1811. The entire diameter of the head measured 1,250,000 miles, and hence its bulk was nearly three times that of the sun, and four million times that of the earth. But such extraordinary dimensions are quite exceptional.

Comets visible to the naked eye almost always have a train or tail. Hence, the appendage is inseparably connected with them in the popular mind, though by far the greater number are really without it. This most remarkable feature of their structure appears as a long cone of pale wan light, apparently a continuation of the nebulosity of the head, streaming in the direction opposite that in which the sun is situated. The Chinese noticed the relative position of the train to the sun before it was remarked by Europeans. In the annals of the dynasty of Thong, an account of a comet which appeared in March, A.D. 837, concludes with the statement, "In general when a comet appears in the morning, the tail extends towards the west; when it appears in the evening, it extends towards the east: this is a constant rule." But there are exceptions; and instead of the direction being followed in a right line, there is usually some curvature exhibited, which, when strongly marked, has given rise to the reported sabre and scimitar-like aspect of the objects. Occasionally two tails have appeared. As many as six distinguished the comet of 1744, which curved in the same direction, and were spread out in the form of an immense fan, the edges being bright and decided, the middle faint, and the intervening spaces as sombre as the rest of the firmament.

Nothing is more surprising than the enormous length of the trains in some instances, and the rapidity with which they are formed. The following are some results of observation:—

		Length of Tail. Miles.
Comet of 1680	. . .	100,000,000
,, 1811	. . .	130,000,000
,, 1843	. . .	200,000,000

In these instances, supposing the tails to have stretched out from the sun, they would severally have extended to the orbit of the earth, nearly to that of Mars, and to the zone of the minor planets. Upon a conspicuous comet becoming visible on its approach to the sun, no trace of a tail is seen. But as it wings its flight towards the solar orb, the head enlarges, the nucleus brightens, and the tail is emitted, gradually increasing in length. Yet the greatest expansion of the head, brightness of the nucleus, and extent of the tail, is not attained until the perihelion is passed, or the point nearest the sun; after which, similar changes occur in a reverse order, till the comet resumes the aspect it had at first, and retires out of sight. In less than twenty days the comet of 1843 shot out its tremendous train of two hundred millions of miles; and in two days an extent of sixty millions of miles was emitted by that of 1680. The potent influence of the sun in producing these extraordinary streams of cometic matter is manifest, though we cannot explain the way, whether by calorific or dynamical agency, the action of intense heat, or a power capable of repelling matter of a certain quality.

It is an old observation, dating from the time of Seneca, that the stars are visible through the substance of comets. The fact has been repeatedly exemplified in modern times, and with reference to stars of the most inferior order of brightness. Sir John Herschel observed Biela's comet in 1832 pass over a cluster of the sixteenth or seventeenth magnitude, which the most trifling fog would have effaced; but the stars continued visible, although the cometic matter interposed between them and the spectator must have been at least fifty thousand miles in thickness. Hence he

remarks, that the highest clouds that float in our atmosphere must be looked upon as dense and massive bodies, compared with the filmy and almost spiritual texture of a comet. The appearance of the nucleus has, indeed, often raised the suspicion of a dense opaque body; but the application of high magnifying power to it has always dispelled the idea. It seems certain, therefore, that comets are agglomerations of vapour of inconceivable tenuity; and hence they wander to and fro in the system, without affecting in the least the motions of the planets, though liable to great disturbances from them. Lexell's comet passed through the system of Jupiter in 1779, without in the slightest degree deranging the satellites, but was itself thrown into a new orbit by the action of the planet, which has ever since rendered it invisible.

The appearance of upwards of six hundred comets has been recorded since the commencement of the Christian era, notices of which, more or less meagre, have been collected by the industry of Mr. Hind, from historical documents. They are distributed through the successive centuries as follows:—

A.D.	COMETS.	A.D.	COMETS.
1— 100	. . 22	1000—1100	. . 36
100— 200	. . 23	1100—1200	. . 26
200— 300	. . 44	1200—1300	. . 26
300— 400	. . 27	1300—1400	. . 29
400— 500	. . 16	1400—1500	. . 27
500— 600	. . 25	1500—1600	. . 31
600— 700	. . 22	1600—1700	. . 25
700— 800	. . 16	1700—1800	. . 64
800— 900	. . 42	1800—1850	. . 80
900—1000	. . 26		
		Total	607

The great number observed in the last century, and during the first half of the present, is of course owing to the increased power of telescopes. The orbits of about two hundred of these bodies have been approximately ascertained. In most cases they seem to have passed through the system in hyperbolas and parabolas, chiefly the latter, and can never, therefore, return to it again unless they are diverted into new paths. About forty are supposed to move in shut orbits, or ellipses, more or less elongated, and are permanently attached to the solar system. The majority of these pass to immense distances beyond the bounds of the known planets, and describe orbits so eccentric, that the place of the focus occupied by the sun appears almost at one extremity. Some of the more remarkable of these bodies may be briefly described.

COMET OF 1680.

This was a very remarkable object, and excited the deepest interest throughout the world by its swiftness and splendour. It came from the regions of space immediately above the ecliptic, and plunged downwards with immense velocity in a direction almost perpendicular to the sun. After whirling round the luminary with increased speed, closely approaching the solar surface, it retired upwards with a gradually retarded pace, and has never since been seen. Newton, Flamstead, Halley, Cassini, Bernouilli, and other distinguished astronomers, intently watched its flight. The comet was seen in the early part of November, in the morning, at Greenwich and Paris, exhibiting the aspect of a round nebulous body. On the 11th, the tail just became visible, appearing through a ten-feet

telescope about half a degree long. On the 17th, it was observed at Rome to be more than 15° in length; and 30° in New England on the 18th. On the 8th of December the comet passed its perihelion; and on the 12th, the tail was seen at Rome to be 70° long. Newton found it reduced to 40° by the 5th of January, 1681. On the 25th, it measured only 6° or 7°; on the 10th of February, it was only 2°; on the 25th, the comet was tailless; and shortly afterwards it disappeared from observation. When sweeping around the sun, its velocity amounted to a million of miles an hour; and it approached the solar surface almost within half the distance of the moon from the earth. Newton therefore computed that when in perihelion it was subjected to a heat two thousand times greater than that of red-hot iron. Yet this body is supposed to recede from the sun to the distance of more than seventy thousand millions of miles, or twenty-eight times that of the planet Neptune. From the correspondence between the intervals of the following years of comets, they are inferred to be different apparitions of the same object:—

	B.C.		A.D.		A.D.		A.D.
Years of Comets	44		531		1106		1680
Years in the Intervals . .		575		575		574	

The first of these epochs was the era of the Julium Sidus, previously mentioned, the long-haired star seen at Rome while the youthful Augustus was celebrating games in honour of his uncle, the assassinated Cæsar. His published memorial respecting it, preserved by Pliny, ran as follows:—" In those days, during the solemnity of my games, there was seen a blazing star for seven days together, in that region of the sky which is under the north star Septentriones. It arose about

the eleventh hour of the day, bright and clear, and was evidently seen in all lands. By that star it was signified that the soul of Cæsar was received among the divine powers of the immortal gods." The next era of apparition brings us to the fifth year of Justinian, when, in the month of September, the comet was seen for twenty days in the western heavens, and received from the Byzantine writers the name of Lampadius, from its resemblance to a burning lamp. At the third epoch, when the second of the Norman sovereigns was on the throne of England, chroniclers describe it as like the blaze of the sun, having an immense train. At the last-named date, when watched by a cultivated science, its phenomena have been stated; and reckoning onwards 575 years from 1680, we have for the period of the next return, the year 2255.

HALLEY'S COMET.

The year following that in which the preceding comet vanished, 1682, another appeared, not so conspicuous as its predecessor, but of greater interest, as the first body of the class whose periodic time was positively ascertained. Dr. Halley's name has been justly stamped upon it, as he observed its position with great care, computed the orbits of other comets recorded in history upon which definite observations had been made, compared them together, sagaciously supposed that some discrepancy as to the periodic time might reasonably be expected from the action of the planets, and finally concluded that it would return in the year 1758-9, having a period of about seventy-five years.

Years of Comets . . .	1155	1230	1305	1380	1456	1531	1607	1682
Years in the Intervals .		75	75	75	76	75	76	75.

Halley's conclusion was based upon the coincidence in their paths between the comets of 1682, 1607, and 1531, which subsequent researches extended to those of 1456 and 1380. It did not rest merely upon the correspondence of the intervals. "Wherefore," he remarked, in announcing the result of his investigation, "if it should return, according to our prediction, about the year 1758, impartial posterity will not refuse to acknowledge that this was first discovered by an Englishman." He had been gathered to the grave in Lee churchyard seventeen years when the prediction was verified.

As the announced time approached, the greatest curiosity about the issue prevailed; but scientific men were in no degree incredulous respecting it, though misgivings were entertained as to circumstances being favourable to the visibility of the comet. "We cannot doubt," remarked Lalande, "that it will return; and even if astronomers cannot see it, they will not therefore be the less convinced of its presence. They know that the faintness of its light, its great distance, and perhaps even bad weather, may keep it from our view. But the world will find it difficult to believe us; and they will place this discovery, which has done so much honour to modern philosophy, among the number of chance predictions. We shall see discussions spring up again in colleges, contempt among the ignorant, terror among the people; and seventy-six years will roll away before there will be another opportunity of removing all doubt." In order to fix the precise time when the comet should be visible by estimating the perturbing action of the planets, Lalande and Clairaut, assisted by Madame Lepaute, engaged in most laborious calculations. "During six months," says the

former, "we calculated from morning till night, sometimes even at meals, the consequence of which was, that I contracted an illness which changed my constitution for the remainder of my life. The assistance rendered by Madame Lepaute was such, that without her we never could have dared to undertake this enormous labour, in which it was necessary to calculate the distance of each of the two planets, Jupiter and Saturn, from the comet, and their attraction upon that body, separately, for every successive degree, and for a hundred and fifty years." Clairaut finally announced, in November, 1758, as the result of their joint labours, that the comet would be retarded 100 days by the action of Saturn, and 518 days by the action of Jupiter. He fixed its return to perihelion on the 13th of April, 1759, but added the precautionary remark, that a body which passes into regions so remote might be exposed to the influence of forces totally unknown, *even of some planet too far removed from the sun to be ever perceived.* In little more than twenty years after this remark, Uranus was discovered.

At all observatories a sharp look-out was kept up for the expected visitor. Voltaire states that astronomers hardly went to bed at all. Messier, who had acquired the name of the "comet hunter," from the number he discovered, was particularly anxious upon the occasion. Of great simplicity of character, his zeal after comets was often displayed in the oddest manner. While attending the death-bed of his wife, and necessarily absent from his observatory, the discovery of one was snatched from him by Montaigne de Limoges. This was a grievous blow. A visitor began to offer him consolation on account of his recent bereavement, when Messier, thinking only of the comet, answered,

"I had discovered twelve; alas! to be robbed of the thirteenth by that Montaigne!" But instantly recollecting himself, he exclaimed, "*Ah! cette pauvre femme!*" and went on deploring wife and comet together. The honour of being the first to verify Halley's prediction was not reserved for any professional astronomer. It was won by an amateur, George Palitzch, a gentleman farmer in the neighbourhood of Dresden, who caught sight of it with an eight-foot telescope on Christmas night, 1758. A few days afterwards it was observed at Leipsic, and within a month, at all the observatories of Europe. But it was so pale and obscure, that it was not seen by the naked eye before it plunged into the sun's rays. The passage of the perihelion took place on the 13th of March, 1759, just one month earlier than the time fixed by Clairaut, yet within the range he allowed for possible errors. After emerging from the rays of the sun, towards the end of March, it appeared like a large star, without any trace of a tail. But in the southern hemisphere, where circumstances were more favourable for observation, a tail was seen of considerable extent.

Another period of revolution has elapsed since the time referred to, during which astronomy made immense advances, especially with reference to computing more exactly the effects of planetary perturbation. Some years before the expected second re-appearance of the comet, the academies of Paris and Turin offered prizes for the most perfect theory of this remarkable body. The former was gained by M. Pontecoulant, and the latter by Baron Damoiseau, who severally predicted its arrival at perihelion on the 7th and the 4th of November, 1835. Its precise route among the stars was also traced with surprising accuracy; and

the particular point of the heavens was indicated to which the telescope should be directed to catch its return to visibility. Early in the year named, it was announced in a leading journal in our own country:— "On the whole, it may be considered as tolerably certain, that the comet will become visible in every part of Europe about the latter end of August or beginning of September next. It will most probably be distinguishable by the naked eye, like a star of the first magnitude, but with a duller light than that of a planet, and surrounded with a pale nebulosity, which will slightly impair its splendour. On the night of the 7th of October, the comet will approach the well-known constellation of the Great Bear; and between that and the 11th, it will pass directly through the seven conspicuous stars of that constellation. Towards the close of November, the comet will plunge among the rays of the sun, and disappear, and not issue from them, on the other side, until the end of December." This prospectus of the movements of a body invisible at the time—millions of miles away—is nearly as definite as the early advertisements of coaching between London and Edinburgh. Let us now place the observations of the eye alongside the anticipations of science. The comet was first discovered by M. Domouchel of the observatory at Rome, on the morning of the 5th of August; by Struve at Dorpat on the 20th; in England and France on the 23d; and at Yale College, in the United States, on the 31st. But it was not distinctly visible to the naked eye till the 22d of September. From this time it moved rapidly through the northern sky; until about the 10th of October it traversed the Great Bear, passing a little above, instead of "through," the seven conspicuous stars of the con-

stellation. Early in November, it ran down to the sun, arrived at its perihelion on the 16th, and re-emerged towards the close of December. After this, passing to the south of the equator, it ceased to be seen in northern latitudes, but remained visible in the southern hemisphere till the month of May, 1836, when it finally vanished, not to return till the year 1911. Thus did science triumph in its determinations, for the approximation to perfect accuracy must be regarded as very surprising, when it is considered that the planet Neptune being unknown, its influence could not be taken into account. The comet approaches the sun within half the earth's distance, and retires from it to above thirty-five times that distance, or considerably beyond the known bounds of planetary space.

It is probable that the observation of Halley's comet may be traced back for two thousand years; and a sketch of past appearances may not be without interest to the reader.

A comet signalized the birth of Mithridates, B.C. 130, believed to be the one under notice; and its *first* recorded appearance. It is said to have been visible twenty-four days; to have surpassed the sun in brightness, an obvious exaggeration; to have extended its train over a fourth part of the firmament; and to have occupied, in consequence, about four hours in rising and setting. But it must not be supposed that ancient accounts of the object are exaggerated because they differ from modern appearances, for it is undeniable that comets undergo great changes; and that the aspect of Halley's has not been so conspicuous since as it was when observed by him. In the year A. D. 323, a comet appeared in the sign Virgo. The interval from the birth of Mithridates to this period, or four

hundred and fifty-three years, is equal to six periods of seventy-five and a half years; and hence it would seem, that in the interim there were five returns of the comet unobserved, or at least unrecorded. Seventy-six years later, or in 399, the Byzantine historians mention a comet, the *seventh* recorded return. This is described as an object "of monstrous size and appalling aspect, its tail seeming to reach the ground." The next reported appearance, after one which is unnoticed, marks the taking of Rome, in the year 550, the *ninth* visit. After a gap of three hundred and eighty years, equivalent to five revolutions, an appearance is recorded, the *fourteenth*, in the year 930; and another, the *fifteenth*, in 1006. This was immediately prior to the Danish dynasty in England, and during the declining days of the empire of the caliphs. The comet is mentioned as having an immense curved tail in the form of a scythe, and a head which appeared four times as large as Venus. No notice occurs of the *sixteenth* return, which must have been about 1082, in the reign of the Conqueror; and the *seventeenth* and *eighteenth*, in 1155 and 1230, are merely mentioned by the annalists, without any descriptive particulars.

The *nineteenth* visit, in 1305, when the papal chair was removed to Avignon, the Swiss cantons were effecting their independence, and Edward I. was tyrannizing over Scotland, is distinctly chronicled. At the season of Easter, the "great and fearful star" was perceived; but, contrary to supposed cometary effects, a general cold prevailed over Europe, and a severe frost in England, at midsummer, destroyed the corn and the fruits. This was "followed by a great plague." In a similar manner, the great plague of London in the reign of Charles II. was popularly attributed to a

comet which signalized the year; though no reason was assigned why the celestial phenomenon did not extend its pestiferous influence to the other towns of the kingdom, and the remaining capitals of Europe. History gives no details of the *twentieth* return, in 1380; but the *twenty-first*, in 1456, is amply recorded. The comet is described as of "unheard-of magnitude," accompanied by a tail of extraordinary length, for it swept over the third part of the heavens, in the form of a sword or sabre. It continued in sight a considerable time, and spread panic throughout Christendom, as it was believed to presage the further triumph of the Turks, who had recently captured Constantinople. Pope Calixtus II. therefore directed the thunder of the church against the enemies of his rule, celestial and terrestrial, formally exorcising in the same bull the comet and the Moslems. At the *twenty-second* return, in 1531, the great events of modern times had taken place, the invention of printing, the discovery of the New World, the route by the Cape, and the ever-memorable Reformation. The comet was observed by Pierre Appian, and exhibited a bright gold colour.

In 1607, the *twenty-third* visit, Kepler and Galileo were about commencing their discoveries. The former saw the comet on the evening of the 26th of September, when it had the appearance of a star of the first magnitude, and to his vision was without a tail. But some friends around him, who had better sight, distinguished it; and before three o'clock the following morning, the tail had become quite visible, having acquired great magnitude. Two days afterwards, it was observed by Longomontanus, who describes its appearance to the naked eye as like Jupiter, but with a more obscure light, and a tail of considerable length. The

course of the comet was watched through the constellations, Ursa Major, Boötes, Serpentes, and Ophiuchus; and, say the chroniclers of its terrestrial effects, "a great war between the Swedes and the Danes;" "the Duke of Lorraine died." When Cardinal Mazarin lay upon his death-bed, an attendant informed him that a comet had made its appearance, upon which he exclaimed, "*La comète me fait trop d'honneur.*" It was gravely maintained by a mediæval sage that "God and nature intended, by comets, to ring the knells of princes, esteeming the bells in churches upon earth not sacred enough for such illustrious and eminent peformances." Shakespeare, in allusion to this sycophancy, states sarcastically,

"When beggars die, there are no comets seen."

The *twenty-fourth* return from the first recorded appearance brings us to the age of Halley.

ENCKE'S COMET.

Though this is a very insignificant object, a particular interest attaches to it. It has never been seen by the naked eye; and unless in a favourable position, it cannot be perceived with the aid of a telescope. The comet, a small globular patch of vapour, without nucleus or tail, and very dim, was first observed by Messier, in the year 1786, traversing the constellation Aquarius. It was next detected by Miss Caroline Herschel, at Slough, 1795, in the constellation Cygnus; and her brother, Sir William, perceived a small star through its middle, with very little diminution of brightness. In 1805, three independent observers caught sight of it on the same day; and one of them,

M. Pons, saw it again in 1818. Down to this date, no suspicion was entertained that these were appearances of the same body. But in the following year, M. Encke of Berlin established this fact, and calculated the orbit of the comet, in consequence of which his name has become associated with it. To the surprise of all astronomers, it was found to revolve in the short period of about three years and a half, in an ellipse of comparatively small dimensions, entirely included within the march of Jupiter, one extremity of which reaches a little beyond the orbit of Pallas, and the other extends to that of Mercury. Announcements respecting its course have been faithfully verified, but with the remarkable peculiarity of the periodic time constantly, though slowly, decreasing, owing to contraction in the magnitude of the orbit. In explanation, the theory has been proposed, that the planets do not revolve in a perfect void; but that a resisting medium fills all space, such as the ether whose vibrations are recognised in the undulatory theory of light. As the effect of this medium, the filmy comet is retarded; and, by projectile force being diminished, increased power is given to the solar attraction, so that the orbit contracts, and the periodic time shortens. The comet is therefore in process of being drawn nearer to the sun; and the ultimate effect, it is conceived, must be the termination of its existence as a separate body, by its merging into the luminary. It is further supposed, that the same cause acting upon the planets must eventually tell upon their velocities, and bring about the entire destruction of the planetary system. But such inferences are quite premature. The indication of a resisting medium afforded by Encke's comet must be confirmed by instances of the

same effect upon other bodies, before it can be accepted as a reality, for there are other ways of accounting for the phenomenon observed. Supposing it to exist, it is quite conceivable, that the comet may be going through a cycle of gradual approach to the sun, to be followed by another cycle of gradual retreat, owing to the action of Jupiter, for the extremity of the cometary ellipse closely approaches the path of the planet. It is positively certain also, that the conjectured medium has not yet had any appreciable effect upon planet or satellite; and until this becomes manifest, the question of its ultimate influence upon the system may well remain in abeyance.

BIELA'S COMET.

Like the preceding, this comet is small and obscure, without nucleus or train, and entirely telescopic; but it is invested with an interest which belongs to no other object in the universe. It takes its name from M. Biela, an Austrian officer, who discovered it in the constellation Aries, on the 27th of February, 1826, while residing at Josephstadt in Bohemia. It moves in an orbit which passes a little within that of the Earth, and somewhat beyond that of Jupiter; and has a periodic time of 6¾ years. The great peculiarity of this body is, that its orbit passes so near to the earth's path, that if the two were to arrive at the point of closest approximation at the same time, they would come in contact. Great alarm that this would be the case was excited among the inhabitants of Paris, in the year 1832, so that it was deemed expedient by the Academy of Sciences to interpose, in order to allay the popular apprehensions. The task being

intrusted to M. Arago, he produced his masterly treatise on comets. It was known, that a little before midnight, on the 29th of October, the comet would be at its most proximate point to the earth's orbit, and that the Earth would be at the same point on the 30th of November, about a month afterwards. The facts were quite true, but the fears of collision were groundless; for as the earth travels at the rate of more than a million and a half miles a day, it was nearly fifty millions of miles away from the comet when the latter swept by its path. The two were in much closer neighbourhood in the year 1805, being only five millions of miles apart; but public attention was not called to their nearness. Biela's comet is also remarkable for an extraordinary change in its constitution, which took place suddenly upon its appearance in the year 1846. It was then seen by various observers in Europe and America to separate into two bodies, which continued to travel together during the whole period of visibility; and both presented short tails, while the original comet was tail-less. The cause of the transformation is perfectly inexplicable. But obviously no fear need be entertained of our hard and solid globe being shattered by collision with such a substance.

COMET OF 1843.

By far the finest object of its class seen during the present century presented itself in the spring of the above-named year, and with a suddenness which had quite a startling effect. But though evidently a comet of the largest class, as seen in our latitudes, its appearance was much more imposing in more southerly

regions. Mr. Maclear, the astronomer at the Cape, states: "Of the casual observatory phenomena, the grand comet of March takes precedence; and few of its kind have been so splendid and imposing. I remember that of 1811; it was not half so brilliant as the late one. Immersed in the ravines of the Cedarberg, with high and precipitous ranges on each side of me, I made strenuous efforts to reach the Snew-berg station, to command a view of the sudden visitor. Those unacquainted with the character of the Cedarberg, cannot form a conception of the difficulties I had to encounter. For seventeen days we toiled on, tantalized every evening by seeing a portion of the tail over the mountain tops, and sometimes a sight of its bright head, as openings in the mountains permitted." The comet was seen in Italy on the 28th of February; at Washington, on the 6th of March; at Oporto, on the 14th; but owing to unfavourable weather, it was not visible in England, or any of the northern countries of Europe, previous to the 17th. A little after sunset on that day, the tail was observed in the western sky, but the head had already sunk below the horizon. The whole of the comet appeared on the following evenings for a short time, for it was travelling away from the sun with great velocity, having doubled the solar orb before it became visible; and about the beginning of April it finally disappeared.

The appearance of this startling stranger, as observed at Washington, is thus described by Lieutenant Maury, of the Hydrographical Office in that city: "On Monday morning, March 6, our attention was called to a paragraph in the newspapers, stating that a comet was visible near the sun at midday with the naked eye. The sky was clear; but not being able to discover any

thing with the unassisted eye, recourse was had to the telescope, but with no better success. About sunset in the evening, the examination was renewed with great diligence, but to no purpose. The last faint streak of day gilded the west; beautiful and delicate fleeces of cloud curtained the bed of the sun; the upper sky was studded with stars; and all hopes of seeing the comet that evening had vanished. Soon after we had retired, the officer of the watch announced its appearance in the west. The phenomenon was sublime and beautiful. The needle was greatly agitated, and a strongly marked pencil of light was streaming up from the path of the sun in an oblique direction to the southward and eastward; its edges were parallel. It was 30° long. Stars could be seen twinkling through it, and no doubt was at first entertained but that this was the tail of the comet. The officer of the watch was directed to search the eastern sky with the telescope in the morning, from early dawn and before, till sunrise. Nothing uncommon or strange was noted by him. Tuesday was a beautiful day. The sun was clear, gilding, as it sank below the hills, a narrow streak of cloud, seen through the tree-tops beyond the Potomac. The tail had appeared of great length the evening before, therefore we expected to find its length this evening greatly increased. It was a moment of intense interest when the first stars began to appear. The last rays of the sun still lingered on the horizon, and at this moment a well-defined pencil of airy light was seen pointed towards the sun. At 5h. 41m., sidereal time, the first measurement of length of the tail was taken: it was 41° to the horizon. At 6h. 19m., it had become most distinct: it was then 55° long, not including the part below the horizon, which, supposing its terminus

to be near the sun, could not, owing to the oblique angle which it made with the horizon, be less than 10° or 15° more."

The tail, as seen in northerly countries, spread over an arc of the heavens of about 40°; but in southern latitudes it extended to from 60° to 70°. It had an absolute length, as before stated, of two hundred millions of miles; so that, had it been coiled around the earth like a serpent, it would have girdled it eight thousand times at the equator. This comet approached still nearer the sun than that of 1680, and must therefore have been exposed to a heat of greater intensity. Its centre is computed to have been within a hundred thousand miles of the solar surface; and according to Sir John Herschel's calculations, it was then exposed to a heat equal to that which would be received by an equal portion of the earth's surface, if it were subject to the influence of forty-seven thousand suns, placed at the common distance of the actual sun. It is difficult to conceive how a flimsy substance in such circumstances could escape being entirely dissipated. But such was its velocity, that it wheeled round the sun in less than two hours.

COMET OF 1858.

This fine object, which will long be had in remembrance, was discovered on the 2nd of June by Dr. Donati, at Florence; and independently, on the 29th of the same month, by Parkhurst, at Perth Amboy, New Jersey, United States. It appeared at first as a faint nebulous patch of light, without any remarkable condensation; and as its motion towards the sun at that time was slow, it was not till the beginning of Sep-

tember that it became visible to the naked eye. A short tail was then seen on the side opposite to the sun. The development was afterwards rapid; and the comet became equally interesting to the professional astronomer, and to the unlearned gazer. In the first week of October, the tail attained its greatest length, 36°, when the beautiful and grand spectacle of the transit over Arcturus attracted the individual attention of the civilized world. The part of the comet which passed over the star was but a short distance from the head; and instead of being dimmed by the interception, the star seemed to glow with greater brightness through it. At this time the tail was sensibly curved, and had the appearance of a large ostrich-feather when waved gently in the hand. At the latter end of October, the comet was lost in the evening twilight. Its nearest approach to the earth was about equal to half the distance of the earth from the sun; and the nearest approach to Venus was about one-ninth part of that distance. An elliptical orbit, with a periodic time of more than 2000 years, has been assigned to our late visitor.

It deserves a record, that a comet which appeared in 1618, passed through very nearly the same district of the heavens as that of 1858, for it made a transit over the same star. In a descriptive tract by "John Bainbridge, Doctor of Physicke," he remarks: "The 27 of November in the morning the comet's hair was spread over the faire starre Arcturus, betwixt the thighs of Arctophylax, or Boötes."

THE EXPECTED COMET.

It is considered very probable, but by no means

certain, that a great comet, revolving in the long period of nearly three centuries, was observed in the years 975, 1264, and 1556. This is the opinion of Gauss of Göttingen, Mr. Hind, and other eminent authorities. Assuming the comets of those years to have been apparitions of the same body, its return towards the sun may be anticipated after the lapse of a corresponding interval; and as full three centuries have just expired since the year 1556, the wanderer is now overdue. But as its period of revolution may be lengthened by planetary perturbation, the look-out will not be deemed hopeless for a year or two longer. It is therefore not unlikely that the comet will revisit these parts of space in either the year 1859 or 1860; and upon this presumption, it will not be without interest to glance at its past epochs and appearances.

In the year 975, the notorious Dunstan was primate and prime-minister of England. The dismal tragedy of Edwy and Elgiva had just been enacted, and that of Edward and Elfrida was nigh at hand. John Zimisces was upon the throne of Constantinople. Many European writers of the period record the appearance of a "bearded comet" in the autumn; and it is also mentioned in the annals of the Chinese. It was seen eighty-three days, from the close of July to the end of October.

The next era, 1264, answers to the forty-ninth year of Henry III., when the patriotic Simon de Montfort was the virtual master of the kingdom, and writs were for the first time issued to cities and boroughs, summoning them to send representatives to parliament. Almost all historians of the thirteenth century mention the comet of the year referred to, many of whom were

eye-witnesses. The "hairy star," or "tailed star," as it is called, was evidently a very remarkable object. "A comet of surprising magnitude," says Ptolemy of Lucca, "was seen in Italy; it appeared first in Cancer, thence advanced gradually towards the south until it approached the constellation Orion; it was visible many months." The chronicle of the Monk of Padua states that "it commenced appearing between the east and north; it shot out its threatening rays towards the west, was first seen in July, and disappeared at the commencement of October." The Belgian chronicle affirms that the comet appeared of such remarkable magnitude, that no one who saw it had witnessed its equal before; for, rising from the east with great splendour, it extended its brilliant tail past the "mid-heaven" westward. The head was obscure, but the tail stretched out far and wide, "resembling in magnitude and form the sail of a ship." The epithets, "notabilis," "insignis magnitudinis," "magnus et clarus," are not spared by the describers. The comet was observed by the astronomers then residing in the north and south of China. All European annalists remark upon the coincident sickness and death of pope Urban IV. "Mention must be made," says Thierri, in a poem on the life of the pontiff, "of the prodigy of a hairy star, which is to apprise us of the death of so great a man. For its first apparition boded his illness, and its disappearance his death, as events have proved. When the pope, Urban IV. was dying, the comet disappeared, as though it had been aware of his death." According to Matthew Paris, the pope died and the comet departed on the same night, October 2.

The third and last era, 1556, corresponds to the last year of the Marian persecution in England, when

Cranmer perished at the stake. The comet appears to have been seen in some places before the end of February, but it was not generally observed till the middle of the first week in March, and it disappeared in the latter part of April. It is described as "a great and brilliant star, training after it a flaming tail of great extent." Its apparent diameter was equal to half that of the moon, and the tail resembled "the flame of a torch agitated by the wind;" an expression doubtless referring to the coruscations which are sometimes visible in the tails of comets. Cornelius Gemma, an eye-witness, states, that when it first appeared, the head was fully as large as Jupiter, and its colour resembled that of Mars, the ruddiness fading at last into a pallid hue. He makes likewise the odd remark, that the tail always at first turned towards Spain. The emperor Charles v. was greatly alarmed upon the occasion, looking upon the comet as a sign of his approaching death. He expressed his fears in a Latin line to this effect:—"*His ergo indiciis me mea fata vocant;*" or, as it appears in French verse:—

> "Par la triste comête,
> Qui brille sur ma tête,
> Je connois que les cieux
> M'appellent de ces lieux."

This alarm is said to have induced him to cede the imperial crown to his son Ferdinand, having already renounced that of Spain in favour of his son Philip.

Should a comet speedily disclose itself to our view, having the same orbit, or nearly so, with that of 1556, which was observed with astronomical instruments, its identity with it will be established, and a new body be added to the system with a periodic time about four times that of Halley's, moving in a vastly more elon-

gated *ellipse. Should no such disclosure* be made, it may still have been drawn back by *the chain* of solar influence, without being visible, owing to unfavourable circumstances for observation. If neither of these events transpire, no reproach will rest upon astronomers, for they have not announced the Expected Comet with the certainty of assertion with which an eclipse or a transit is predicted, but simply as a matter of fair probability. Thus all that science has ventured to state upon the subject amounts to a surmise of a very harmless nature. Yet some mischief-makers not only converted the probability into a certainty, but spread a panic through various sections of society, in 1857, by the rumour of a dreadful collision impending between the comet and the earth. The false representation might be deemed far too stupid to deserve notice, were it not that popular terrors are often productive of very serious consequences. At Paris, in 1773, on the occasion of a similar panic, persons of weak minds died of fright, and knaves were not wanting to turn the alarm to their own advantage by selling places in paradise at high prices.

The general question of the probability and the consequences of a collision may be legitimately entertained. With reference to the first point, it cannot be denied that collision is rigorously possible; but at the same time it is so extremely improbable, that it may be safely dismissed from apprehension. The fact of such an event not having been experienced in the known course of terrestrial history is surely some guarantee against its occurrence. Another may be found in the small volume of the earth and of comets when compared with the immensity of space in which they move. According to the well-understood principles of proba-

bilities, Arago has calculated, that upon the appearance of a new comet, the odds are as 281,000,000 to 1, that it will not strike against our globe. The probability, therefore, of such an event happening in the experience of any individual is no greater than that of his drawing out of an urn containing the above number of balls, a single black one, all the rest being white. But even supposing collision to occur, all that we know of the constitution of comets justifies the conclusion, that the encounter would involve no terrestrial convulsion, nor any result incompatible with full security to life and happiness. Nothing, therefore, can be more absurd than for men to concern themselves with such an incident. Rather should we dwell with the utmost seriousness upon the certainties of our condition, as the creatures of a day, who will soon have to give an account to God; and so improve the opportunities of the present life, that through the merits of his Son, we may be accepted of him who will be our Judge.

CHAPTER XIII.

THE STELLAR HEAVENS.

Solitariness of our System—Night Scene—Twinkling of the Stars—Their Artificial Grouping—Different Magnitudes—Formation of the Constellations—Aratus and St. Paul—Zodiacal Constellations—Their supposed Origin—The Pleiades—Northern Constellations—The Great Bear—Arcturus—The Pointers—Familiar Comparisons—Southern Constellations—Halley and Lacaille—Sirius—Orion—The Cross—Number and Distance of the Stars—Parallax—Frauenhofer's Refractors—Bessel's Determination of Parallax—Other Determinations Instabilities of the Firmament—Lost Stars—New Stars—Apparitions of 1572 and 1604—Kepler—Variable Stars—Stella Mira—Algol—Lalande—Multiple Stars—Prevalence of Pairs—Discovery of Herschel—Colour of the Stars—Contrasted Colours in Multiple Systems—Proper Motion of the Stars—Translation in Space of the Solar System—The Milky Way—Island Universes—Conclusion.

PROCEEDING outwardly through the system, we have passed in succession planet after planet, and reached the frontier limits of the great family of worlds to which the earth belongs, forming the mighty empire of the sun. What is the spectacle in view? Standing at this remote point, the orbit of Neptune, nearly three thousand millions of miles out in space, and looking backward, the keenest vision of man will not be able to descry more than a single planet, Uranus. The rest are as though they were not, the distance being too great to admit of their being seen, while the sun himself has so shrunk in appearance, as to be scarcely of greater magnitude than the morning and evening star. Occasionally a comet, moving with laggard pace when so distant from the luminary, either passes beyond the circumference of planetary space, outward-bound on a cruise in the surrounding regions, or returns from a visit to those mysterious realms. But while nearly

all the members of the system are thus out of view at the point indicated, still with reference to the overarching stellar canopy, no change whatever is perceptible. The stars, after such an alteration of distance, are not apparently nearer or farther off, not brighter or duller, not more numerous or less so, or altered in the least in their configurations. There is Orion with his bands, Arcturus and his sons, the Dog-star, and the Greater Bear. Each and all, as seen from the latest found and farthest planet, are just as they appear from the hills and valleys of our world. The fact is, that great as are the dimensions of the system to us, the entire line of its diameter is of very trifling extent, when compared with the vast length of the passage through unoccupied space to the nearest of the stellar host. All the interplanetary distances together make up but a small area in contrast with the vastness of the surrounding solitude. In relation to that solitude, the planetary orbits may be likened to a few circular pathways, only a few yards apart, each with its antique stone, inclosing a larger central one, placed in the middle of an apparently boundless plain, on which no other monument is found.

On a cloudless and serene night, the spectacle of the firmament is one of the most glorious that nature presents to the eye of man. The number of glittering points aloft in the sky, their varying brightness, striking configuration, rapid twinkling yet calm regularity, combine to excite feelings of admiration in the mind of the observer, while inspiring curiosity respecting the wonderful exhibition. But the scene is far more imposing in southern climes than in northern latitudes, owing to the greater transparency of the atmosphere

rendering the stars more lustrous; and the same effect is remarked on the tops of lofty mountains, as the consequence of elevation above the denser air of the lower regions. It is also observed, that at high sites and in serene climates, the stars shine with the most steady lustre. Their twinkling being caused by sudden compressions and dilatations of the molecules of the air changing its refractive power, and producing the apparently agitated emission of light, the scintillation may be expected to be least marked in situations where the atmosphere has its smallest volume and least density. The same effect is not so obvious in the case of the planets, because of their disks, which, though small, are of sufficient magnitude to bear with little disturbance the minute agitations of the air, whereas the stars being only brilliant points, with no perceptible diameter, are completely displaced. To common observers, the stars appear to preserve the same relative distance in the heavens, while the planets are seen to change their positions. Hence they became known in early times as *inerrantes*, "fixed;" and they are still popularly generalized under this designation, though the advance of science has shown it to be inaccurate. For the same reason they were poetically styled the "Eyes of Providence."

ARTIFICIAL GROUPING OF THE STARS.

The stars are distributed into classes according to their apparent magnitudes, estimated by their relative degrees of brightness. But this classification is vague and unsatisfactory. It has not been determined by any definite scale, but left in a great measure to the decision of the eye alone; and as the power of vision varies in

observers, stars have been ranked as of the same order which considerably differ in their brilliance. About twenty in the whole heavens are reckoned of the first magnitude, being brighter than any of the rest, or "starres of the first lyghte," as they are termed in the quaint but expressive phraseology of bygone times. The next brightest, of the second magnitude, amount to from fifty to sixty. The next, of the third rank, to about two hundred. The number of each class increases rapidly as we descend the scale of brightness, down to the sixteenth magnitude; but all beyond the sixth are invisible to the naked eye, and are therefore called telescopic stars. The light of Sirius, the brightest in the heavens, is estimated to be more than three hundred times that of an average star of the sixth order.

In the most ancient times, the stars with which mankind were familiar were arranged in groups, or constellations, and named after various objects, mythological personages and animals, which the groups were supposed to resemble, or whose imaginary outlines were arbitrarily attached to them. This division of the heavens, analogous to the distribution of the earth into countries, kingdoms, and states, is convenient for the sake of easy reference, however faulty the execution of it; and so long has the popular mind been familiarized with it, that confusion would arise from its abandonment. At what period, and by whom, the first constellations were traced in the sky, are points involved in complete obscurity. They probably originated with the Chaldeans or Egyptians, and were multiplied by the early Greeks and Romans. Eudoxus of Cnidus, who died about B.C. 368, a contemporary of Plato, in one of his works, called the *Phænomena,*

enumerated all the constellations then recognised. This production is lost, but a poetical version of it is extant, made about a century afterwards by Aratus, a Cilician, probably a native of Tarsus, which Cicero translated into Latin hexameters. It is remarkable for being quoted by the Apostle Paul when at Athens—"For in him we live, and move, and have our being; as certain also of your own poets have said, For we are also his offspring."

> "Jove fills the heaven, the earth, the sea, the air;
> We feel his spirit moving here, and everywhere.
> *And we his offspring are.* He, ever good,
> Daily provides for man his daily food.
> Ordains the seasons by his signs on high,
> Studding with gems of light the azure canopy.
> What time with plough and spade to break the soil,
> That plenteous stores may bless the reaper's toil;
> What time to plant and prune the vine he shows,
> And hangs the purple cluster on its boughs.
> To Him—the First, the Last, all homage yield,
> Our Father wonderful, our help, our shield."

Aratus mentions forty-five constellations, namely, the twelve zodiacal, with twenty in the northern hemisphere, and thirteen in the southern. Ptolemy subsequently added three more, one in the northern, and two in the southern heavens. These forty-eight ancient groups are all represented on our celestial globes. The moderns have originated nearly an equal number, or forty-five, chiefly in the southern hemisphere, for the sky of the south was largely unknown down to the close of the fifteenth century. Stars in each group are indicated in the order of their brightness by the letters of the Greek alphabet; but some are always mentioned under names which have become identified with them, as Sirius, Canopus, Fomalhaut, and others.

The twelve zodiacal constellations are those which

the sun appears to traverse in the annual circuit of the heavens. As the forms and names of nearly all of them are those of animals, the zone which they compose received the name of zodiac, from the Greek *zodion*, the figure of an animal. There is some plausibility in the suggestion, that in forming these asterisms, the ancients were guided by terrestrial occupations and phenomena coincident with the sun's appearance in them. Thus Aries, Taurus, and Gemini, respectively the Ram, the Bull, and the Twins, (the latter originally two goats,) are supposed to allude to the animals let loose in the fields, or held in the greatest esteem in the spring months of the ancient world. The principle in question is sufficiently illustrated by this reference to it. These groups in the solar highway comprise five first-class stars—Aldebaran, of a somewhat ruddy appearance, in Taurus; Castor, a remarkable double star, in Gemini; Regulus, sometimes called Cor Leonis, in Leo; Spica Virginis, known by its solitary splendour, in Virgo, therefore called by the Arabs the "unarmed or defenceless Simak;" and Antares, of a fiery red aspect, in Scorpio. Taurus is the richest of the zodiacal groups in stars. It is easily distinguished by the clustering Hyades, which make, with Aldebaran, the letter V; and the more conspicuous Pleiades, referred to in holy writ. Six stars are ordinarily visible to the naked eye in the latter cluster, but the ancients reckoned seven. The fate of the lost one has exercised poetical imagination. But according to the power of vision possessed by individuals, six, seven, or even more, are discernible; and upwards of a hundred have been reckoned with the aid of the telescope. "Canst thou bind the sweet influences of the Pleiades?" was an interrogation

addressed by the Almighty to Job, intended for the instruction and correction of all mankind. It calls upon them to contrast their own infirmity with the mighty and mysterious power of God, exemplified in a mere nook of the visible universe, to be humble before him, and to fear his name.

The northern hemisphere is parcelled out into thirty-five constellations, of which twenty-one are ancient. Of the fourteen added in modern times, which are mostly unimportant, Hevelius contributed nine, and Tycho Brahe, Halley, Bede, Poczobat, and Lemonnier, respectively, one each. Ursa Major, or the Great Bear, is the most strongly marked and familiarly known group; for being near the north celestial pole, it never descends below the horizon in our latitude, and is constantly present in the unclouded night-sky of the whole of Europe. The constellation has no resemblance whatever to the animal after which it is designated; but the bear was probably elevated to the polar sky as an inhabitant specially of northerly regions. It is remarkable that the Iroquois, a tribe of North-American Indians, were found, upon the discovery of the continent, designating this part of the heavens, like the earliest Arabs of Asia, by a term signifying the "bear." Probably the constellation is included, with the neighbouring Ursa Minor, or the Little Bear, and Boötes, the Herdsman, also called Arctophylax, the Bear-driver, in the reference made to "Arcturus with his sons," in the book of Job. Arcturus is a first-class star in Boötes, and the name is a Greek compound, denoting the Bear's tail. "Canst thou guide Arcturus with his sons?" is another impressive challenge addressed to the children of men, to reflect upon their own littleness and the capacity of Omnipotence.

The Great Bear is mentioned under the name of Helicè in classical antiquity, as in the celebrated description of the night by Apollonius Rhodius:—

> "Night on the pour'd darkness; on the sea
> The wakesome sailor to Orion's star
> And Helicè turn'd heedful. Sunk to rest
> The traveller forgot his toil; his charge
> The sentinel; her death-devoted babe
> The mother's painless breast. The village dog
> Had ceased his troublous bay. Each busy tumult
> Was hush'd at that dead hour; and darkness slept,
> Lock'd in the arms of silence."

Seven stars are conspicuous in the constellation: thirty-five were reckoned by the naked eye before the age of the telescope, and between three and four hundred have been revealed by the instrument. Of the prominent stars, two are called the Pointers, because an imaginary line from the lower to the upper, carried on in the same direction, leads the eye to the pole-star, in Ursa Minor, near the true north polar point. The upper of these stars, Dubhe, and the lower, Merak, with two others, Megrez, upper, and Phad, lower, are so arranged that lines connecting them form a quadrangle. The remaining three, beginning with the nearest to the quadrangle, are respectively called Alioth, Mizar, and Benetmasch. Similarly connected, the resulting shape is triangular, and has been compared to that of a reaping-hook and a note of interrogation. The middle star has a minute companion, almost touching it, called Aleor, which appears double and of a silver white through a telescope. But the Arabs term it *Saidak*, signifying "trial" or "test," owing to their use of it to try the goodness of vision. Of the seven stars noticed, the three form the tail of the bear, and the other four part of the body. By the old shepherds the cluster was known as the Dipper

or Ladle. In this homely but more apt illustration, the three stars are regarded as forming the handle, and the four the bowl of the utensil. Formerly, in our own rural districts, the cluster was familiarly styled Charles's Wain, a corruption of the Gothic, *Karl Wagen*, the churl's or peasant's cart. According to this fancy, the four stars of the quadrangle formed the wagon, and the other three the shafts and horses. The imagination has also found in the group the representation of a funeral, viewing the stars of the quadrangle as defining the bier or hearse, and the remaining three the mourners following it.

The southern constellations amount to forty-six, of which only fifteen are ancient; for, previous to the circumnavigation of Africa by the Portuguese, no knowledge of the southern sky in high latitudes was possessed by Europeans. For the purpose of scientific observation, Halley sailed to St. Helena in 1676, and spent two years upon the island, engaged in cataloguing the stars of the hemisphere. With the same object in view, about the middle of the last century, Lacaille proceeded to the Cape of Good Hope, and resided there several years. Of the thirty-one groups formed by the moderns, two are due to Halley, two to Hevelius, fourteen to Lacaille, twelve to Bayer, and one to Royer. The southern hemisphere contains the brightest star in the whole heavens, Sirius, often called the dog-star, from its position in Canis Major, the Great Dog. No object in the firmament was more celebrated in superstitious ages. The old Egyptians saw the star rise heliacally, or a little before the sun, when the Nile began its annual overflow; and regarding the coincident events as physically connected, they adored Sirius as the author of the fertility of their country. But the

Greeks and Romans viewed the stellar orb as the special patron of heat, fever, pestilence, because, rising with the sun in the most sultry season of the year, its influence seemed to blend with that of the luminary in producing these effects. This season was therefore called *dies caniculares*, or "dog-days," a phrase which is still in use, but only having reference to the summer solstice. Homer speaks of

> "The star
> Autumnal—of all stars, in dead of night
> Conspicuous most, and named Orion's dog
> Brightest it shines, but ominous and dire
> Disease portends to miserable man."

The southern hemisphere also contains the most magnificent group in the firmament—Orion—visible to all parts of the habitable globe, because intersected centrally by the equinoctial. Its outline, that of a long square, or parallelogram, is formed by four principal stars, of which two are of the first magnitude, Betelgeux at the upper, and Rigel at the lower end. Three stars of the second magnitude, arranged obliquely in a straight line, near the middle of the square, form the "belt" of the mythological personage; and another row to the south, smaller and more oblique, represents the "sword." These are the "bands of Orion" mentioned in sacred writ, more familiar to the human race collectively than any other stellar forms. The uppermost star in the belt being very little to the south of the equinoctial, is almost exactly vertical to the earth's equator. This fine constellation was regarded by the ancients as unpropitious, the cause of storms and tempests, an object, therefore, of fear and trembling to the mariner. Virgil thus makes Æneas account for the storm which interrupted his course to Italy:—

> "To that bless'd shore we steer'd our destin'd way,
> When sudden, dire Orion roused the sea.
> All charg'd with tempests rose the baleful star,
> And on our navy poured his watery war."

These ideas of the ancient mind ought to make us thankful for the volume of Divine revelation, which enables us to read aright the book of nature; and teaches us to regard every sun that shines and star that twinkles, every wind that blows and ocean that roars, as equally, with ourselves, in the hand of God. He it is, in the words of Job, "which alone spreadeth out the heavens, and treadeth upon the waves of the sea; which maketh Arcturus, Orion, and Pleiades, and the chambers of the south; which doeth great things past finding out; yea, and wonders without number." The friendship of such an Almighty Being must assuredly be infinitely desirable, while no words can adequately express the fearfulness of living in the violation of his laws, and of dying exposed to his frown. Hence the propriety and importance of the prophet's exhortation—"Seek him that maketh the seven stars and Orion, and turneth the shadow of death into the morning, and maketh the day dark with night: that calleth for the waters of the sea, and poureth them out upon the face of the earth: The Lord is his name."

Of the forty-six constellations of the southern hemisphere, twenty-one are never visible in the latitude of London, for we can only see the stars as many degrees south of the equinoctial, as our own latitude lacks of 90°. The most interesting group beyond our ken, and one of the finest objects in the heavens, is the Southern Cross, consisting of four bright stars so disposed as to admit of the cruciform shape being readily given to them. Having considerable southerly declination, it

is not seen till the tropics have been entered, nor is it prominent till the equator is approached. The constellation is also the most useful one in the southern sky. The two great stars which form the summit and foot of the cross, having nearly the same right ascension, are almost perpendicular on passing the meridian; and hence the hour of the night is known, according as the cross is erect or inclined. The same stars are also of the greatest service to navigators, as they are the Pointers to the south celestial pole.

NUMBER AND DISTANCE OF THE STARS.

In both hemispheres the total number of stars visible to the naked eye is very limited, not greatly exceeding five thousand in the case of the keenest gazers. They seem, indeed, at first sight, incalculable, but close scrutiny speedily proves this to be an illusion, caused by their twinkling, irregular scattering, and the indistinct manner in which they are viewed. But the moment the vision is aided by instrumental power, the first impression of the eye is found to represent the reality. With a telescope of moderate capacity, the night-sky everywhere becomes an astonishing spectacle, both to the senses and the understanding, for new worlds burst upon the sight in the spaces that before seemed void; and the number thus disclosed to view continually increases with every augmentation to optical power. All space seems filled with luminous bodies, which bewilder the imagination by their multitude, and admit of being joined with the sand of the ocean's beach, as a figure of speech denoting a numeration which no arithmetic can express. Eyery one is acquainted with that irregular fog-like zone called by the ancients the

Milky Way, from its colour and appearance, which passes quite round the heavens, and is the only real and sensible circle in the sphere. Though more or less visible at all seasons of the year, yet in northern latitudes it is seen to the best advantage in the interval between the close of July and the beginning of November. It varies in different parts of its course in breadth and brightness, having the largest development and the greatest brightness in the southern circumpolar region. After it had excited the curiosity and wonder of mankind for ages, its stellar composition was demonstrated by the telescope, though its multitudinous host of stars remained a secret till the elder Herschel turned his giant instrument upon the belt. He revealed its thick-sown glories, which might stagger a seraph's computation, for it is composed entirely of stars scattered by millions like dust upon the black ground of the general heavens. "What Omnipotence!" was the involuntary exclamation of Schroeter of Lilienthal, upon examining a portion of the magnificent girdle. The southern hemisphere is thought to be somewhat richer in stars than the northern.

One of the ancients affirmed that there is no easy way from the earth to the stars, meaning to intimate, that immortality was not attainable by common efforts. But, undesignedly, he uttered a great astronomical truth, upon which clear light has been thrown in our own age.

It has been already remarked that the solar system is in the midst of a vast solitude. Above—below—on every side—there extends an abyss of awful magnitude. It may not be a perfect vacuum, and probably is not; but it contains no bodies analogous to the sun and the planets. This complete isolation of the system is

obviously necessary, in order to preserve its internal harmony; for if there were such bodies proximate, their disturbing action would introduce derangement. Hence empty, as well as occupied space, displays the wisdom of the Creator—abstinence from formative acts, as well as positive demonstrations of power. But what is the extent of the great gulf around us? in other words, what is the distance of the stars? When the system of Copernicus began to be discussed, it was alleged as an argument against it, that if the earth revolved round the sun in the enormous ellipse supposed, and with the consequent velocity, such a vast and rapid displacement, amounting to 190 millions of miles, the diameter of the orbit, must necessarily cause a corresponding great apparent change in the position of the stars. But not the slightest movement of the kind being observable, the theory was confidently pronounced to be untrue; and the fixed, immutable stars, were appealed to as a bright host of witnesses to its absurdity. The reasoning was perfectly sound; and could only be met by the unsupported assertion, that, owing to the immense distance of these bodies, no perceptible change was occasioned by the revolution of the earth in its orbit.

In walking along the high road, or travelling by railway, the objects upon which the eye rests in the surrounding landscape—trees, houses, and hedgerows—appear to change their place in consequence of our own locomotion. This seeming movement is more or less perceptible, in proportion as our velocity increases or slackens, and as the object is nigh at hand or distant. The apparent displacement is called *parallax*, a Biblical as well as an astronomical term, for it occurs in the impressive representation—"The Father of

lights, with whom is no variableness (literally *parallax*), neither shadow of turning." If, after shifting our position a certain distance, and accurately ascertaining its length as a base line, we measure the angle subtended by the visual ray directed to a particular object from the two extremities, or the parallax, the length of the visual ray is readily determined, and the distance of the object by the simplest rules of geometry. Now astronomers have a base line at their command in the diameter of the earth; and with reference to the sun, moon, and planets, it suffices to produce a sensible and measurable parallactic angle. But it fails utterly in the instance of the fixed stars, for the visual rays from the extremities of this base are perfectly parallel in their direction, or, in other words, there is no appreciable parallax. It remained, therefore, to apply to the same purpose the diameter of the earth's orbit, a base line of comparatively enormous length, or 190 millions of miles, for to this extent the place of an observer is shifted every six months by the earth's annual revolution. Still the visual rays sent up to the far distant star from opposite points of the terrestrial orbit yielded no parallactic angle; and the only result gained for a time, respecting the distance of the stars, was, that it must be immense indeed, since the most careful and delicate instrumental tests failed to detect the slightest parallax. But it was known that a parallax of a single second, or $\frac{1}{3600}$th part of a degree, if it existed, could not possibly have escaped notice; and as this amount would imply a distance equal to 200,000 times that of the sun, it followed that no star could be at least within nineteen billions of miles.

The problem of the stellar distance remained in this condition, with a merely negative solution, from the

time that Bradley made a series of careful observations upon γ Draconis, to the effect stated, in 1725-27, down to the year 1834, when M. Bessel, of Königsberg, directed his attention to it. He had command of one of the magnificent refracting telescopes, for which the world is indebted to Frauenhofer, of Munich, furnished with a micrometrical apparatus of wonderful perfection. "To give some idea," observes Mr. Michell, "of the delicacy of the contrivance with which these great telescopes have been provided, it is only necessary to state that the micrometer of the refractor of the Cincinnati observatory is capable of dividing an inch into eighty thousand equal parts. When mechanical ingenuity failed to construct lines of mathematical minuteness, the spider lent his aid, and it is with his delicate web that these measures are accomplished. Two parallel spiders' webs are adjusted in the focus of the eye-piece of the micrometer; and when the light of a small lamp is thrown upon them, the eye, on looking through the telescope, sees two minute golden wires, straight and beautiful, drawn across the centre of the field of view, and pictured on the heavens." With mechanical aid still more delicate, and of a somewhat different kind, Bessel applied himself to the star, 61 Cygni, in the hope of finding the hitherto unattained parallax. Night after night, in favourable weather, it was watched, with reference to a number of minute stellar points adjoining, till a variation began to show itself, increasing exactly as parallactic variation ought to increase, and diminishing as it ought to diminish. The changes accomplished their cycle in precisely a year; and in every respect corresponded to those which ought to be produced by parallax. During another year, the observations were

repeated, with a like result, and a confirmation of the previous values. This was the case after a third year spent in careful and elaborate investigation. Bessel therefore announced, in the year 1838, that he had discovered the annual parallax of 61 Cygni, and had measured the great gulf between us and the sphere of the fixed stars.

The parallax detected by the Prussian astronomer places the star at a distance equal to 600,000 times the distance of the sun, or fifty-seven billions of miles. To appreciate this interval, it may be remembered that light, travelling with the velocity of twelve millions of miles every minute of time, reaches us in about four hours from the remotest planet, but will require nearly ten years to compass the sidereal space in question. The accuracy of Bessel's results has been established in the most satisfactory manner; and subsequently, by a similar method, the absolute distance of other stars has been determined by various observers. The nearest yet measured, *a* Centauri, a fine double star in the southern hemisphere, is 220,000 times the distance of the sun; Sirius is 800,000; and Arcturus, 1,600,000. The two latter, therefore, require twelve and twenty-four years for the transmission of their light. Yet these distances only bring us to the skirts of the firmament, or, as it were, to the threshold of the great temple of the skies, for poetry but enshrines a sober inference in the statement,

> "How distant some of the nocturnal suns!
> So distant, says the sage, 'twere not absurd
> To doubt, if beams, set out at Nature's birth,
> Are yet arriv'd at this so foreign world;
> Though nothing half so rapid as their flight."

It follows necessarily from the distance of the stars

that they are themselves suns, and may each be the centre of a scheme of subordinate bodies like our own sun, as isolated and independent as the solar system.

LOST, NEW, AND VARIABLE STARS.

The immutability of the heavens, a doctrine propounded by Aristotle, and accepted for ages as an incontrovertible fact, has been completely exploded by modern observation, like other parts of ancient philosophy. So far back as the year 1670, Montanari, struck with the evidences of celestial change, projected a work on the "Instabilities of the Firmament," devoted to a record of them. "There are now wanting in the heavens," he remarked, "two stars of the second magnitude in the stern and yard of the ship Argo. I and others observed them in the year 1664, upon occasion of the comet that appeared in that year. When they first disappeared I know not; only I am sure, that on the 10th of April 1668, there was not the least glimpse of them to be seen." The extraordinary fact does not rest upon individual testimony, for there are many well-authenticated cases of the entire disappearance of old stars, whose places had been fixed with a degree of precision excluding the possibility of mistake. A star in the constellation Hercules, regularly entered in Flamstead's catalogue, was twice observed by Sir William Herschel, who particularly noted that it was *red.* But nine years after his last observation. it was missing, and has never since been seen. In a similar manner, Sir John Herschel missed one in the year 1828, in the constellation Virgo; and no search has since been able to detect it.

On the other hand, new stars have occasionally made their appearance, and have vanished from the sky, after astonishing mankind by their brilliance. Two thousand years ago, an object of this kind is said to have induced Hipparchus to make a catalogue of the stars, the first on record, preserved to us by Ptolemy, in order that any changes in the heavens might be readily detected by future observers. He fixed the places of 1081 stars, with as much accuracy as the rude instruments at his command permitted; and afterwards made a representation of the heavens on the surface of an artificial globe, which was deposited in the library at Alexandria. New stars are recorded in the years 389, 945, and 1264 of our era; but we must come down to the sixteenth century for an example, of which a detailed description survives. In the year 1572, a remarkable object suddenly became visible in the constellation Cassiopeia, shining with great splendour, and occupying a position which had before been blank, immediately under the scabellum, or chair. It was first perceived by Schuler, of Wittemberg, on the 6th of August; next by Cornelius Gemma on the 9th of November; and by Tycho Brahe on the 11th. The latter was walking across the fields to his home, about 10 o'clock at night, when he first observed it, and met with a group of peasants intently gazing upon the novelty. The light was so brilliant as to cause his staff to deflect a shadow; and he watched the star carefully while it remained visible. At the brightest, it is said to have been seen in the day-time, but this lustre was only retained a short period. It changed colour upon declining in splendour, passed from a white to a yellow hue, then became reddish, and, finally, faintly blue. It disappeared in

March 1574, after being visible about eighteen months, and has never since been seen.

Thirty years later, in 1604, when the planets Mars, Saturn, and Jupiter, were in close proximity to each other, and attracted universal attention, a new star blazed forth in the constellation Serpentarius, at no great distance from Jupiter, far surpassing him in brightness. It was observed by the scholars of Kepler on the 30th of September, but, owing to unfavourable weather, he did not gain a sight of it till the 8th of October. It gradually waned like its predecessor, exhibited different hues, disappeared early in the year 1606, and no telescopic power has since been able to detect any star in the place once occupied by the stranger. Kepler wrote a treatise upon it, entitled, *De Stellâ Novâ*, a presentation copy of which to our James I. is in the library of the British Museum. "What," says he, "it may portend is hard to determine; and thus much only is certain, that it comes to tell mankind either nothing at all, or high and weighty news, quite beyond human sense and understanding." In allusion to the opinions of some, who explained the novel object by the Epicurean doctrine of a fortuitous combination of atoms, he remarks, with characteristic oddity, yet good sense, "I will tell these disputants, my opponents, not my opinion, but my wife's. Yesterday, when weary with writing, and my mind quite dusty with considering these atoms, I was called to supper, and a salad I had asked for was set before me. 'It seems, then,' said I aloud, 'that if pewter dishes, leaves of lettuce, grains of salt, drops of water, vinegar and oil, and slices of egg, had been flying about in the air from all eternity, it might at last happen by chance that there would come a salad.' 'Yes,' says

my wife, 'but not one so nice or well dressed as this of mine is.'" No sensible parallax was ever detected in either of the objects referred to; and hence they undoubtedly belonged to the region of the fixed stars. Other examples, but of a less remarkable nature, are on record; and no satisfactory explanation has yet been given of the phenomena.

It is observed of a considerable number of stars, that they are subject to periodical changes of brightness, some becoming absolutely invisible, and then returning into view. These are classed as variable stars. This peculiarity has been long noticed in the case of *o* Ceti, a star in the neck of the Whale, and was first remarked by Fabricius in the year 1596. It obtained, in consequence, the name of *Stella Mira*, or the "wonderful star." For about a fortnight it is seen as a star of the second magnitude; then it gradually diminishes during three months, passes wholly out of sight, remains invisible about five months, and, after coming into view, gains, in three months more, its former brightness. It goes through this series of variations in the period of 330 days; but it is sometimes invisible longer, and does not always return to the same degree of lustre. Algol, or β Persei, in the head of Medusa, is still more remarkable for the shortness of its cycle of change and the regularity of its phases. The star, at the brightest, appears of the second magnitude, and remains so for about 2 days 14 hours. Its light then diminishes, and so rapidly, that in 3½ hours it is reduced to the fourth magnitude. It wears this aspect rather more than 15 minutes, then increases, and in 3½ hours more, resumes it former appearance. The changes are thus gone through in 2 days, 20 hours, and 48 minutes. The astronomer Lalande, who died

in Paris in 1807, is said to have often posted himself, in his old age, on the *Pont Neuf*, to show to the curious the changes of Algol. Other stars exhibit similar variations, completed in a cycle of years, or even centuries. Among the conjectures offered to account for these mutations, it has been suggested that they may arise from variations of distance, the stars so affected moving in orbits more or less elongated, so placed as to have one of the narrow extremities presented towards our system. This theory may obviously be extended to embrace the apparition of new stars, and those that have departed from their place in the heavens. But it has no title to be regarded otherwise than as a speculation.

MULTIPLE STARS.

In a multitude of instances, stars which seem single points of light to the naked eye are resolved by the telescope into combinations of two or more individuals, and are termed double, or binary, triple, and quadruple, according to the number of the components. The twin-stars, or binary systems, are by far the most numerous, and have been the longest known. Dr. Hook noticed one in the year 1664, but made the remark, that the like example he had never before seen in the heavens. The middle star in the tail of the Great Bear was noted to be double on the 7th of September, 1700, by Godfrey Kirch, as well as by his celebrated and scientific wife, Mary Margaret. But while only a few examples were known, no importance was attached to them, as it was supposed that such appearances were caused by the casual position of two stars in the same direction, the one being at a great

distance behind the other. There can be no doubt that in some instances the proximity is simply optical; but stellar pairs are scattered throughout the heavens with far greater profusion than is conceivable as the result of accidental optical contiguity. It has been aptly remarked, that if we suppose a number of peas to be thrown at random upon a chess-board, we should certainly expect to find them occupying irregular or random positions. If, contrary to this, they were, in far more than average numbers, found to be arranged in pairs on each square, the rational inference would be, that here there was no random scattering. The conclusion has been established beyond all doubt in a great number of cases, that the bodies visibly associated are really proximate, and physically connected. The double stars amount to many thousands in the northern hemisphere alone; triplicates are not uncommon; quadruple, and even quintuple stars have also been detected.

In the course of his diversified researches, Sir W. Herschel formally proposed to himself to solve the problem of the parallax of the fixed stars, by means of the double stars, which he then supposed to be only optically connected. But an unexpected observation stopped the investigation of parallax, in order to develop a new discovery. He found the stars of many pairs to be actually in motion, one revolving around the other, or, more properly, both revolving around a common centre of gravity in elliptical orbits. This wonderful spectacle of revolving suns, moving in obedience to the same influences which hold the planets in their career, each perhaps attended by a train of dependent bodies, vies in interest, as a discovery, with any ever made in the annals of astronomical science. It extended in the most absolute manner the great law

of gravitation to the fixed stars, and justified the confidence which led Newton to affirm the influence wherever matter existed or motion was exhibited. The evidence of this revolution in the components of a binary or multiple system is as certain as that which we possess of the march of Jupiter and the planets round the sun. Since observation commenced, more than a complete revolution has in some cases been accomplished, while in others, the changes of relative position have supplied data for approximate calculations of the periodic time. The constituents of η Coronæ have a period of 44 years, while the revolution of those of Castor is supposed to extend to 250 years, and much longer terms are assigned in other instances.

The declaration of the inspired writer, that "one star differeth from another star in glory," is strikingly true of those within the range of the unaided vision, both as to their lustre and their tints, though the latter diversity is not so obvious to us, owing to a hazy atmosphere, as to the dwellers in tropical lands. Still they perceptibly vary in their hues, and the respective hues are variously intense. Sirius, Lyra, Spica Virginis, Bellatrix, Atair, and Vega are white stars; Procyon and Capella are orange-coloured; Aldebaran, Antares, Arcturus, Rigel, Pollux, and Betelgeux, are red. It is remarkable that Sirius, now so decidedly and brilliantly white, is expressly distinguished by two of the ancients, Ptolemy and Seneca, as a red star. Hence there has either been a change in the colour of its light, or the observation was the result of some optical peculiarity. Sir W. Herschel generally saw objects with a redder tinge than other observers; and it is well known that sharp eye-sight is sometimes accompanied with an utter inability to distinguish

certain hues. No stars of other colours besides those named were recognised by the ancients, nor yet by the moderns, till the multiple systems disclosed the curious and beautiful phenomenon of contrasted or complementary tints. While the constituents of a double star are in many cases of the same complexion, they are often also strikingly different, white, red, blue, green, yellow, and violet-coloured stars being associated. This is sometimes doubtless an optical illusion merely, as a white light will appear greenish when near a strong red one, and acquire a blue tinge when the neighbouring colour is yellow. But the hues are frequently too decided for all of them to be simply the effect of contrast. The elder Struve of Dorpat has given the following analysis of 596 binary systems :—

375 pairs of the same colour and intensity.
101 pairs of the same colour, but different intensity.
120 pairs of totally different colours.

Among those of the same colour, the white pairs are the most numerous, estimated at two and a half times the number of the red ones; and the red pairs are reckoned at twice the number of the bluish. Struve observed a blue star attending upon a differently-coloured primary, as follows :—

53 times,	with a white principal star.				
52	,,	,,	a light yellow principal star.		
52	,,	,,	a yellow or red	,,	,,
16	,,	,,	a green	,,	,,

It is quite impossible to conceive, as Sir John Herschel has remarked, " what variety of illumination *two suns*, a red and a green, or a yellow and a blue one, must afford a planet circulating about either; and what

charming contrasts and 'grateful vicissitudes'—a red and a green day, for instance, alternating with a white one and with darkness—might arise from the presence or absence of one or other, or both, above the horizon." Isolated white and red stars are met with in various parts of the heavens, the latter as deep as blood; but no instance has been noticed of a decidedly blue, green, purple, or violet-coloured star occurring solitary.

PROPER MOTION OF THE STARS.

While lost, new, and variable stars, however obscure such incidents in themselves, distinctly intimate activity in the regions of stellar space, it is clear, from the revolutions detected in the multiple systems, that the term "fixed" is not rigorously applicable to them. Nor does absolute fixity appear to belong to any orb in the universe, though the relative situations of stars have a high degree of permanence. Many have a proper motion in a given direction in space, slow but constant, and very appreciable after long intervals of time. It has also been inferred, that our own sun is in motion likewise. This was the view of the elder Herschel, previously entertained by others, but carefully elaborated by him, founded upon the observed displacement of the stars. He came to the conclusion, that the solar system is moving in a grand path towards a point in the constellation Hercules. He conceived, as the result of searching scrutiny, that the stars in this particular region of the heavens are spreading out, or becoming farther and farther apart, while those in the opposite region are closing up, becoming nearer and nearer, just as, in proceeding through a forest, the trees towards which we are

advancing seem gradually to separate, and those we leave behind as gradually to approach. Though the best living astronomers of the day received the announcement with distrust, and the theory fell into disrepute; yet recent investigations, founded upon more extensive data, tend not only to confirm the fact of the movement, but its direction likewise. The combined researches of Argelander, Peters, and the younger Struve, justify, in their opinion, the belief, that "the sun, attended by all its planets, satellites, and comets, is sweeping through space towards the star π in the constellation Hercules, with a velocity which causes it to pass over a distance equal to 33,350,000 miles in every year." The reality of the solar motion is very generally admitted, but it will not be considered to be demonstrated, nor the direction and velocity of the journey be allowed, till practical astronomy has furnished a much larger series of observations in favour of such conclusions. But if the solar system is really proceeding through space in any direction, it must be in a mighty orbit around some centre of gravity, or central sun, in connexion with that great scheme of stars of which it is presumed to be a member.

ISLAND UNIVERSES.

Reference has been made to the wonderful and lucid tract known to the Greeks as the Galaxy, and to the Latins as the Via Lactea, or Milky Way, an immense assemblage of stars arching the heavens, and making nearly a complete circle of the sphere. This is conceived to be a definitely-formed stellar stratum, thin, in proportion to the length and breadth, which, being seen in the line of its greatest extent, causes the appear-

ance of the milky zone projected on the concave surface of the sky. Being much more brilliant in the southern than in the northern hemisphere, it is supposed that our sun is eccentrically situated in relation to it, being the nearest to those parts that are most conspicuous. It is open to observation, that, while distant from the zone, the stars appear insulated, as if outliers, there is a crowding of them together at nearer points, towards that perfect agglomeration to the naked eye, which forms the Milky Way. Thus we pass from the idea of a solar system, consisting of a central star or sun, with planets and satellites revolving round it, to the far grander conception of a stellar scheme, composed of myriads of solar systems, many of them, perhaps, surpassing our own in magnitude. Yet this is only an item in the treasury of God's works, for inconceivably more distant than our fixed stars similar Milky Ways appear, "island universes," as the Germans call them, exhibiting different, but often well-defined shapes, hanging in sublime perspective in the depths of space. More than four thousand of these remote star-systems have been descried, but the real number seems to be bounded only by the incapacity of our means for exploring the heavens. They are spoken of as nebulæ, owing to their cloud-like appearance. Some are resolvable into individual stars, while others defy the power of the mightiest telescopes to separate their components. There are globular, annular, crab-like, dumb-bell, whirlpool, or spiral nebulæ, with other remarkable and startling diversities of shape. The mind is overwhelmed, the imagination bewildered, by this display of system after system, firmament ranging after firmament. But here we are at the boundary which divides the known from the unknown; and it

is a relief to pause, while, in that spirit of deep humility and lively adoration which becomes all finite beings, we unite in the testimony—"Great and marvellous are thy works, Lord God Almighty." "Thou art worthy, O Lord, to receive glory, and honour, and power: for thou hast created all things, and for thy pleasure they are and were created."

In thus surveying the range of the creation which mortals are enabled to scan, we have unveiled to us magnitudes and spaces of inconceivable extent; forms and motions of incomprehensible grandeur; order and harmony of unspeakable sublimity. The remark is obvious and pertinent, that however vast the universe, and multitudinous the worlds within its visible bounds, the representations of Scripture are sufficiently comprehensive and striking to express all the emotions which naturally arise in the mind when contemplating its structure. Though issued at a time when human ideas of dimensions and distances were derived chiefly from terrestrial standards, they have not become inadequate, since the scenery of the skies has been illustrated in its majestic proportions by modern science. This fact forms by itself no mean argument, that the sacred pages were written by the inspiration of the same Being who made the worlds, who alone knows the variety of his works, and the amplitude of his dominions. "Ah, Lord God! behold, thou hast made the heaven and the earth by thy great power and stretched-out arm, and there is nothing too hard for thee:—the Great, the Mighty God, the Lord of hosts is his name, great in counsel, and mighty in work." "O Lord God of hosts, who is a strong Lord like unto thee? Thou hast a mighty arm: strong is thy hand, and mighty is thy right hand." "Canst thou

by searching find out God? canst thou find out the Almighty to perfection? It is as high as heaven; what canst thou do? deeper than hell; what canst thou know?—If he cut off, and shut up, or gather together, then who can hinder him?" Though finite minds cannot grasp the idea of omnipotence, yet we can dwell upon the fact, that by its energy all suns and systems were called into existence, launched in space, and are upheld in being, while to its government we ourselves are continually subject. The thought is a consoling one if we have "peace with God through our Lord Jesus Christ;" its entertainment is salutary as a restraint to creatures compassed about with infirmity; but the mighty hand of God will inevitably be a terror to those who, by persisting in the transgression of his laws, provoke a scourge.

However immense the scale of the universe, and innumerable the "mansions" in the "Father's house," all worlds and creatures are intimately known to him, are under the superintendence of his eye, and participate in the visitations of his care. "He telleth the number of the stars; he calleth them all by their names;" while "a sparrow falleth not to the ground without him," and "the very hairs of your head are all numbered." The Psalmist recognised his down-sitting and up-rising, with his entire path, and every word upon his tongue and thought in his heart, as known to God, just as though no other being besides himself existed to be an object of notice; and never for a moment in the view of the Creator is the individuality of the creature lost in the vastness of the creation. It is an astonishing conception, but a most useful thought, that we are

"... ever in our great Taskmaster's eye;"

that He is at hand and afar off, filling all things and upholding all things, doing according to his will in the army of heaven, while in every nook and corner of our world he puts forth his finger of light, and is ever ready to manifest his presence of love. "What is man, that thou art mindful of him!" we may well exclaim, remembering our demerits, and surveying the magnificent circuit of the skies. Yet so it is; and we are bound to receive the truth with gratitude, and improve it wisely. Specially "God commendeth his love towards us, in that, while we were yet sinners, Christ died for us;" and all concerns are unimportant, compared with that of reaping from this wonderful manifestation of his mercy its designed and promised benefits—the present remission of our sins, followed by a peaceful walk with God on earth, and glorious communion with him for ever in eternity and heaven.

A heathen, who only dimly apprehended the great book of the universe, and knew nothing of the greater book of revelation, could yet reflect upon the folly of mankind, as exemplified in their pursuits and cares being so completely identified with this world. "Is it," said he, "to this little spot that the great designs and vast desires of men are confined? Is it for this that there is so much disturbance of nations, so much carnage, and so many ruinous wars? Oh folly of deceived men to imagine great kingdoms in the compass of an atom, and to raise armies to divide a point of earth with the sword!" But human folly is far more conspicuously and lamentably displayed by those who have access to the book of revelation as well as of nature, and are so absorbed with the cares of this life,

as to pay no attention to its contents. What will it avail them in the hour of death to have heaped up riches, or acquired honours? "What is a man profited, if he shall gain the whole world, and lose his own soul?" The Christian, and only he, familiar with the contents of both volumes, acts the part of the wise man and true philosopher. He earns his bread by the sweat of his brow as an appointed duty. He may study with interest and profit the wonderful works of God visible to the fleshly eye, "to make known to the sons of men his mighty acts, and the glorious majesty of his kingdom." But his highest aim and ultimate end is so to pass through this sublunary scene, in humble dependence upon the Divine mercy and grace, as to be prepared to have part in the promised future distinction—"They that be wise shall shine as the brightness of the firmament; and they that turn many to righteousness as the stars for ever and ever." "There is one glory of the sun, and another glory of the moon, and another glory of the stars: for one star differeth from another star in glory. So also is the resurrection of the dead."